

DESCRIPTION AND OPERATING INSTRUCTIONS
OF
USW MARLER RECEIVER
TYPE MH-56-II

1960

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I. INTRODUCTION

The type MPH-56-II marker radio receiver forms a part of an instrument blind landing system.

The marker receiver receives the signals of marker radio beacons and designed for signaling the passage of the aircraft over points located at definite distances from the landing strip. If the marker receiver is operating at the moment of flight over a beacon, a signal lamp lights up and a bell rings up.

The working frequency of the type MPH-56-II marker receiver is 75 Mc/s; the amplitude modulation frequency is 3000 c/s, the modulation factor 30%.

The sensitivity of the receiver is within 1.5 to 3 mV at an output current of 9 mA flowing through the relay coil.

The audio frequency passband of the receiver, measured at a level of 0.5 of the resonance value, is not narrower than 0.7 Mc/s and at the 0.1 level not wider than 7.5 Mc/s. The audio frequency tuning frequency is 3000 c/s $\pm$ 5%.

The radio frequency passband of the receiver, measured at the level of 0.5 of the resonance value is 700 to 1100 c/s, and at the 0.2 level not wider than 2700 c/s.

The tuning frequency of the intra-fuselage antenna is 75 Mc/s $\pm$ 70 Kc/s.

The bandwidth of the intra-fuselage antenna, measured at a level of 0.7 of the resonance value, is not narrower than 200 Kc/s. The travelling wave radio of the feeder is not less than 0.7.

The relay of the receiver operates at a current of not more than 7 mA, and releases at a current of not less than 4 mA, the current of reliable operation is 9 mA.

The anode circuits of the receiver may be supplied from any d.c. source having a voltage of 220 v.

The current consumed by the anode circuits of the receiver does not exceed 22 mA.

The valve heater circuits of the receiver, the electric bell and the signal lamp are supplied by the aircraft network of 27 v.

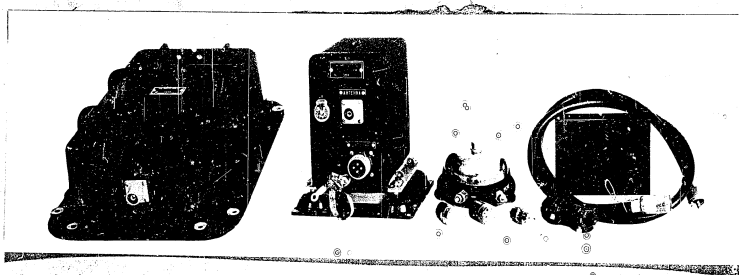


Fig.1. Complete MPH-56-II receiver with intrafuselage antenna

II. PRINCIPLE OF OPERATION

The principle of operation of the MPN-55-II radio receiver consists in the recognition and detection of pulses generated by a marker radio station, into the pulses of the same frequency, which actuate a relay which switches a signal lamp on the operator's instrument board and an electric bell.

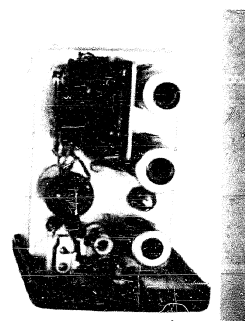
The radio reception signals are received by the intra-fuselage (or external C-shaped) antenna and applied by feeder to the receiver input.

The incoming signal is amplified by an RF stage, rectified, amplified by a three-stage audio frequency amplifier, rectified and the aid of 6H15N-7 (or 1-102) diode and applied to the input of a d.c. amplifier, the circuit of which includes the relay winding.

When the current flowing through the winding attains a certain value, the relay operates and its contacts make the supply circuit of the signal lamp and electric bell.

The MPN-55-II receiver employs 6H15N and 6H15N valves. From an external point of view, the intra-fuselage antenna of the MPN-55-II receiver is an unbalanced, greatly shortened dipole located in a metal cavity and tuned to resonance with parallel loading capacitors. The general view of the antenna is shown in Fig. 1, the circuit diagram in Fig. 3.

Radio frequency voltage is taken from part of the dipole and applied by cable to the receiver.



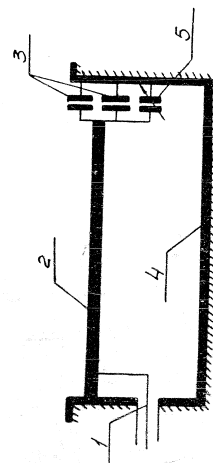


Fig. 3. Schematic diagram of intra-tube antenna
1. R.F. cable 2. Element 3. Loading capacitor 4. Cavity 5. Binding capacitor

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The point of connection of the cathode resistor is chosen to ensure matching of the input impedance of the antenna to the 75-ohm radio frequency cable.

The loading capacitance consists of two type TL capacitors of various temperature coefficients of capacity, which ensures constant antenna parameters within a temperature range of $+30^{\circ}\text{C}$ to -60°C . The approximate capacitance is 20000 pF.

A variable capacitor of 1-1 pF, which serves for fine tuning of the antenna to the working frequency, is connected in parallel with the loading capacitance.

VII. RECEIVING CIRCUIT

The circuit diagram of the receiver is shown in Fig. 2.

The signal of 75 Mc/s, received by the antenna, is applied to the radio frequency cable to a tap of the coil of the input tuned circuit $L_1 C_1$. The point of connection of the feeder is selected in such a way as to ensure matching between the input impedance of the radio frequency amplifier and the characteristic impedance of the feeder.

The voltage developed across the input circuit is applied to the control grid of the RF amplifier valve (6X6H, V_1). The amplified radio frequency voltage is developed across the tuned circuit $L_2 C_2$ which is the anode load of the radio frequency amplifier.

The input and anode circuits are tuned with the aid of brass plugs located inside the coils L_1 and L_2 . With a view to increasing the rectangularity of the H.F. amplifier response curve, the resistor R_2 is connected in series with the anode load. Voltage is supplied to the anode and the screen grid of the valve V_1 via the dropping resistor R_3 . Resistor R_3 and capacitor C_3 form an a.f. decoupling circuit.

Grid bias for the valve V_1 is developed across the cathode resistor R_1 . The valve cathode is bypassed for radio frequencies by the capacitors C_4 and C_5 . The voltage developed across the

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med circuit $L_2 C_5$ is applied via capacitor C_7 to the grid of the 1st triode of the valve 6BH (V_2), which operates as a grid detector.

Radio frequency voltage is developed across the resistor R_1 . The 3000 c/s voltage developed across the anode load of the detector is applied via capacitor C_8 to the grid of the 2nd triode of the valve V_2 which amplifies it.

The anode circuit of the 2nd triode of the valve V_2 includes a radio frequency tuned circuit consisting of capacitors C_9 and the inductance of the choke L_3 , tuned to 3000 c/s.

Voltage from the radio frequency tuned circuit is applied via capacitor C_{10} to the grid of the 1st triode of the valve V_3 (6BH).

The 1st triode of the valve V_3 serves as the output amplifier of the audio frequency voltage. The voltage of 3000 c/s is applied across the anode load of the output amplifier is rectified by a diode (for $\lambda - 402$), and applied to the grid of a rectifier (for $\lambda - 402$).

The anode circuit of the a.c. rectifier includes the relay which is connected to the anode load of the rectifier via capacitor C_{11} . The relay is connected to the anode load of the rectifier via capacitor C_{11} . The relay is connected to the anode load of the rectifier via capacitor C_{11} . The relay is connected to the anode load of the rectifier via capacitor C_{11} .

When a signal is applied to the anode load of the rectifier, the a.c. rectifier valve operates and the anode load of the rectifier is connected to the anode load of the rectifier via capacitor C_{11} .

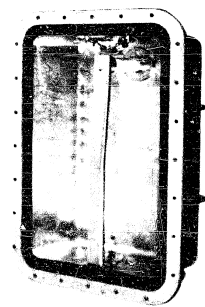
When the anode current attains a certain value, the relay operates, its contacts closing the 27-v circuit which supplies the electric bell and the signal lamp.

Voltage is supplied to the anode of the valve V_3 via the sliding resistors R_{11} and R_{12} .

The antenna cavity is made in the shape of a rectangular box with the front wall removed. The outside of the box has four stiffening ribs. The antenna element is made in the shape of a narrow strip, the edges of which are bent for stiffening, which is arranged along the cavity. With the aid of screws, one end of the element is secured to the box, the other end to an

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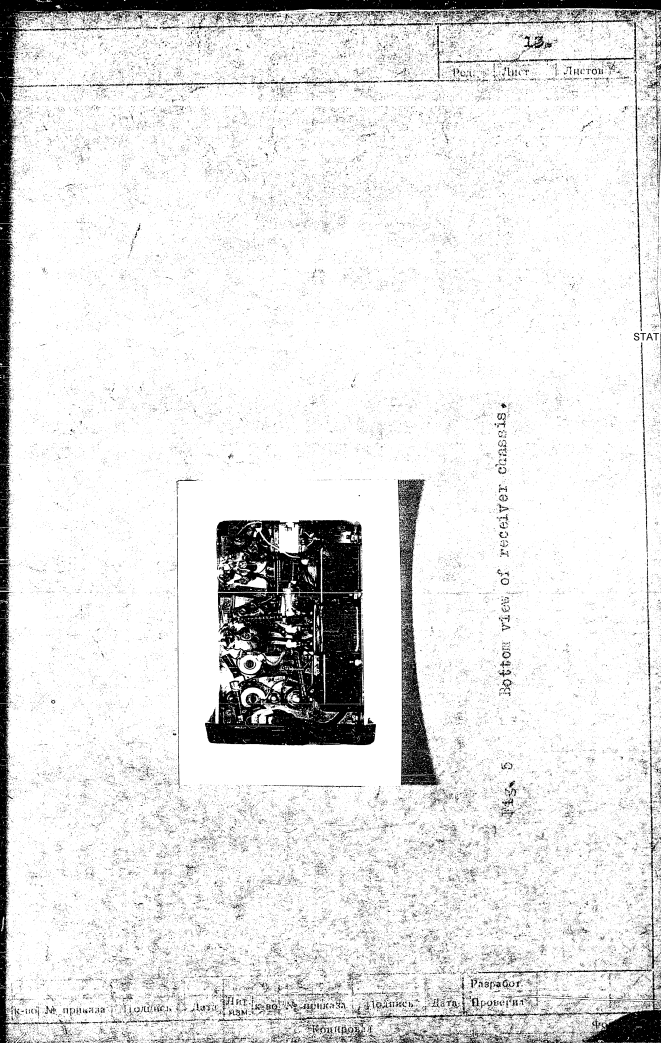
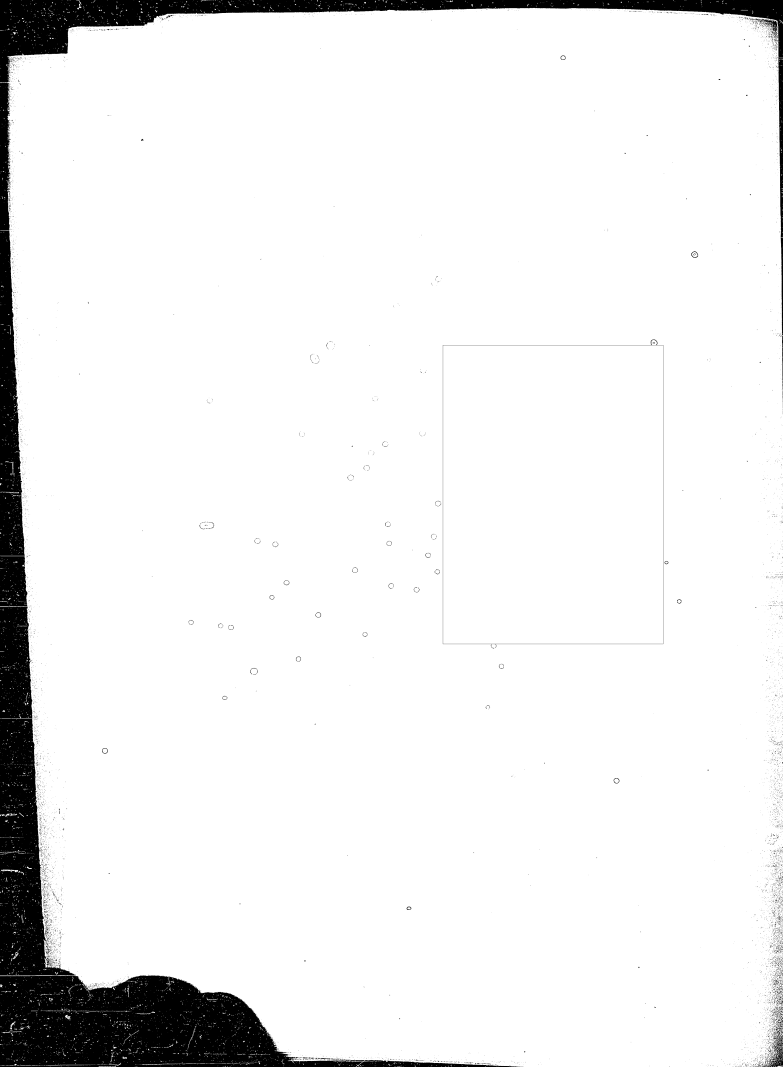
Ref. Sheet 1, 11/1/10



Ref. Sheet 1, 11/1/10

Warning:

In order to connect the receiver chassis to the aircraft body an earthing binding post is mounted at the bottom of the front panel of the receiver.



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The chassis and front panel are inserted into an aluminum casing and secured in it with the aid of two screws located on the side wall of the casing.

The casing with the receiver are mounted on a shock-absorber frame with the aid of four latches. In its turn the shock-absorber frame is secured rigidly to the aircraft body.

V. INSTALLATION OF THE RU-56-II RECEIVER

1. Installing the receiver in the aircraft.

When installing the RU-56-II receiver with an external antenna, it is necessary to consult the wiring-dimensional diagram in Fig. 10.

The external antenna is stretched between two plastic antenna uprights mounted on the bottom of the fuselage.

A tap is made in the middle of the antenna, which should be passed via a through insulator secured in the bottom of the fuselage.

When installing the equipment with an intra-fuselage antenna, the wiring-dimensional diagram in Fig. 11 should be consulted.

The intra-fuselage antenna is installed in the lower part of the fuselage. The installation site of the antenna is selected in such a way that the organic glass lid would not be struck by gravel during take-off and landing. The antenna may be displaced sideways from the flight axis within $\pm 5^\circ$ of the width of the fuselage at the place of installation of the antenna. A window, the size of the organic glass lid is cut in the fuselage sheathing, and the antenna is secured in it, with the lid down. The outside surface of the lid should be flush with the aircraft sheathing. The antenna is installed so that the element would be parallel to the flight axis.

The antenna box should have an electrical contact with the aircraft sheathing.

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Warning:

1. The use of gaskets between the antenna and the aircraft body is impermissible.

2. When painting the aircraft, take care that the organic glass lid is not painted.

The receiver is installed in any place inside the aircraft, but not farther than 8 metres from the antenna, this distance being determined by the attenuation of the antenna feeder per unit of length. For this reason, extending the feeder beyond 8 metres, entails a reduction in the guaranteed sensitivity of the receiver.

The receiver with the shock-absorber frame is secured horizontally inside the aircraft, the following requirements being taken into consideration when selecting the site:

a) The possibility of free access to the receiver for examining and checking it, replacing valves, checking relay current, etc.

b) The possibility of connecting and disconnecting the receiver, removing it from the shock-absorber frame, and setting it back again.

2. Connecting the receiver and checking its operation

After installing the receiver in the aircraft it is necessary to connect the receptacle of the antenna feeder to the "antenna" plug of the receiver and to connect the supply receptacle to the four-pin "supply" plug of the receiver. For reliable contacts, the union nuts should be screwed down fully.

A table is given below which should be consulted when setting-up the supply receptacles.

Connection of supply receptacle

Number on supply receptacle	Connected to
1	2
1	"- 27 V from aircraft network and
К-во: № приказа	Подпись
Дата	Дата
Рис. №	Рис. №
Подпись	Подпись
Дата	Дата
Проверка	Проверка
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1. "-" 220 v from supply source

2. "+" 27 v from aircraft network

3. "+" 220 v from supply source

4. No signal lamp on pilot's instrument panel and to electric bell

Depending on the operating conditions, the "+" 220 v may be connected to one of the d.c. sources of the aircraft, for example to "+" 220 v from the dynamotor of the radio semiconductor, or the dynamotor of the communication radio station. The "-" 27 v is connected to the minus of the aircraft network on the common supply panel of the aircraft. The "+" 27 v is connected to the low voltage (27v) switch of that dynamotor from which the high (220) voltage is taken, as the MHI-56-II receiver is not furnished with a separate switch it is switched on and off from the control panel of the equipment from which it is supplied.

In general, the MHI-56-II marker receiver is installed for operation in conjunction with other equipment designed for the blind landing of aircraft. In such cases it is necessary to consult the instructions and wiring-dimensional diagrams of the complete aircraft blind landing equipment, when installing the MHI-56-II receiver.

After the MHI-56-II receiver is installed in the aircraft and all the necessary connections are made, a preliminary check up is made. For this it is necessary to:

- Switch on the toggle switch (on the control panel) which supplies supply voltage to the receiver;
- Apply a signal of 75 Mc/s from a special tester (a low power transmitter of the marker beacon type which serves for measuring purposes), which is set up at a distance of several metres from the aircraft, to the receiver antenna;

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o) Set the modulation frequency switch of the tester in the position corresponding to a modulation frequency of 3000 c/s;

d) Connect a d.c. milliammeter having a scale of 15-20 milliamperes to the jack "КОНТРОЛЬ" ("CHECKING") on the front panel of the receiver, with the aid of a jack plug.

When a signal is applied from the tester, the milliammeter will indicate the output current flowing through the receiver relay. While varying the value of the signal from the tester (for example, by varying the power output or varying the distance to the receiver antenna), make sure that the relay operates at a current of not more than 7 mA, when the lamp on the pilot's instrument panel should light up and the bell ring. At currents of not less than 4 mA, the relay should release, the lamp go out and the bell stop ringing;

e) The receiver is switched off by means of the same switch on the control panel. After ascertaining that the receiver is operating normally (according to the pre-flight checking procedure detailed above), make sure that the equipment operates normally in flight. When flying over a marker beacon, the signal lamp should light up at an altitude of the order of 2000-3000 metres on condition that the beacon is in order.

The MPI-56-II receiver provides normal operation within a temperature range of -60°C to $+50^{\circ}\text{C}$ and a relative humidity of 98%.

Under such conditions the sensitivity of the receiver may worsen to 4.5 millivolts.

On being installed in the aircraft, the adjusted equipment does not require any re-tuning in operation, as it is tuned to one fixed frequency of 75 Mc/s.

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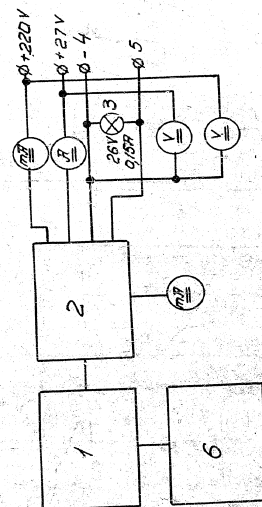


Fig. 6. Block diagram of circuit for measuring receiver parameters.

1. Signal generator, ГСО-7 (or ГСО-17).

2. МРП-56-II receiver, 3. V 4. common-

5. electric-bell relay 6. Audio generator 31-2A

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The tuning should be checked not less than once a month, in case of unstable weather and night flights. Before each flight, in this case the check-up should be carried out according to the method set in the order indicated in article 2 of this section.

Equipment:

The 1011-50-11 interference-resistant receiver ensures the reception of modulated signals differing in modulation frequency from 2000 c/s by not more than 150 c/s.

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Fig. 1. Block diagram of circuit for checking the tuning frequency of the intra-lattice antenna.

1. H-48 2. H-50 3. H-50 intra-lattice antenna

1. H-48 2. H-50 receiver

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3. Checking the main parameters

The main parameters are measured during periodic checking after the end of the guarantee term, after repairs and after replacing valves.

These measurements should be made in an equipped work shop or laboratory by skilled engineering and technical personnel.

A workbench is required for measuring, which is equipped according to the block diagram in Figs. 6 and 7.

For measuring the main parameters the following instruments are required:

- Standard signal generator, type Γ CC-7.
 - Audio generator, type 2Γ -2A (2Γ -1, 2Γ -10).
 - Milliammeter for 30 ma.
 - Milliammeter for 15-20 ma with a low internal resistance (not more than 100 ohms).
 - Ammeter for 1 amp.
 - D.C. voltmeter for 300 v.
 - D.C. voltmeter for 30 v.
 - Marker beacon imitator, type MMH -48.
- Directions for using the above instruments are contained in the operating instructions of the instruments.

a) Measuring sensitivity

A signal of 75 Mc/s from the V.H.F. standard signal generator PCC-7, amplitude modulated by a frequency of 3000 c/s to a depth of 30% is applied to the receiver input. A d.c. voltmeter for 15-20 ma is connected to the jack "KONTROL" ("CHECKING") on the front panel of the receiver. A signal lamp is connected to the contact circuit of the output relay. The tuning slugs of the coils L_1 and L_2 are turned to obtain exact tuning to 75 Mc/s.

The sensitivity of the receiver is determined as the value of the output voltage of the standard signal generator PCC-7

(with allowance for the voltage calibration curve), applied from the attenuator at which the current in the relay winding equals 9 ma.

b) Checking the r.f. bandwidth of the receiver

For measuring the bandwidth at a level of 0.5 of the resonance valve, the output voltage of the TCC-7, corresponding to a relay-winding current of 9 ma, is doubled. The bandwidth at this level is determined as the sum of the de-tunings to each side at which the relay-winding current decreases to 9 ma, as read from the frequency setting dial of the TCC-7.

The bandwidth at the 0.1 level is determined in a similar way, the signal of the standard signal generator being increased tenfold.

c) Checking the tuning frequency of the a.f. filter

With the frequency of the TCC-7 remaining constant, we vary the modulation frequency to obtain maximum reading of the milliammeter.

The tuning frequency of the a.f. filter is read from the dial of the audio frequency generator.

d) Checking the a.f. bandwidth of the receiver

The output voltage of the TCC-7 is set for a relay-winding current of 5 ma. The bandwidth at the 0.5 and 0.2 levels of the resonance value is determined from the audio-generator dial, as the sum of the de-tunings to both sides of the resonance frequency at which the relay-winding current decreases by 2 and 5 times, respectively.

Note: When measuring the bandwidth, the initial current of the output valve (the no-signal current) should be taken into account, which should be added to 5 ma, and correspondingly to the currents of the 0.5 and 0.2 levels.

e) Checking the adjustment of the output relay of the receiver.

Slowly increasing the output voltage of the TCC-7, note

f) Checking the tuning frequency of the intra-fuselage antenna.

The marker beacon simulator is set up on one side of the field, the receiver, connected by feeder to the antenna, on the other side.

The distance between the simulator and the shield is selected such that the maximum reading of the milliammeter would not exceed 9 ma.

Warning:

Warning:
The simulator should be checked carefully against crystal controlled equipment, or equipment which has in its turn been checked against crystal-controlled equipment.

4. Maintenance and checking in operation

4. Maintenance and checking in accordance with instructions
Throughout the service life of the receiver, all the general instructions pertaining to airborne radio equipment should be strictly followed.

observed. Special attention should be paid to the reliability of all contact connections, for example, the contacts of the supply connector plug and socket, the connection of the antenna leader to the receiver and the antenna, etc.

Attention should be paid that the union nuts of connectors are screwed down tight, the spring latches securing the receiver to the shock-absorber frame are fully latched.

If valves or the antenna have been replaced, or the receiver repaired, the operation of the assembly should be checked according to article 4 of this section.

The output relay of the receiver is designed for 2.5 million operations and does not require any adjustment during its service life.

Maintenance of the intra-fuselage antenna consists in wiping the organic-glass lid with a dry or alcohol-moistened cloth.

Warning!

It is **FORBIDDEN** to wipe the organic-glass lid with oily rags.

The antenna, having been tuned at a works laboratory, requires no re-tuning throughout its service life.

The valves of the receiver need not be replaced oftener than those of ordinary communication receivers, as the valves operate under normal, even somewhat reduced voltages.

To facilitate checking of the receiver, a table of valve operating conditions (voltages with respect to the chassis) are given below.

Table of voltages (in volts) with respect to the chassis, at the sockets of the valveholders, with the valves installed, an anode voltage of 320 v and a heater voltage of 27 v.

Valve type		
6N11I (V ₁)	6N31I (V ₂)	6N31I (V ₃)
0	6.3 } $\frac{1}{9}$	6.3 } $\frac{1}{9}$
+ 1.9	0	+ 0.55
6.3 } $\frac{2}{4}$	-0.2	0
	+ 70	+60
+ 120	0	0
+ 120	+ 160	+220
+ 1.9	0	0
-	+ 3.3	+ 8.5
-	6.3 } $\frac{1}{9}$	6.3 } $\frac{1}{9}$

NOTE: 1. Measurements should be made with a voltmeter having a resistance of about 5000 ohms per volt.

2. Depending on various samples of valves and the tolerances of resistors, the voltage values may vary within $\pm 30\%$.

5. Storing and conserving (greasing) the equipment

The equipment should be stored in warehouses in accordance to the general requirements for storing airborne radio equipment.

For conserving, the receiver, the antenna, the electric bell, the supply connectors and the r.f. feeder should be wrapped in greased paper and packed into the corresponding compartments of the packing box.

For deconserving the equipment, the supply connectors, the connectors of the r.f. feeder, the terminals of the electric bell and all the latches and securing projections of the receiver casing and the shock-absorber frame should be carefully degreased with first grade gasoline.

After installation in the aircraft, the receiver should be checked according to article 2 of section V of these instructions.

The works guarantees trouble-free operation of the APR-30-M marker receiver during 4000 flying hours throughout 3 years, including not more than 2 years of actual operation in an aircraft, the rest of the time being made up of transportation and storage at warehouses of the Purchaser and User.

6. Simple faults and methods of eliminating them

In finding faults it is recommended to consult the following table:

Nature of fault	Description of fault	Method of eliminating fault	Note
1. When the relay operates, O/c in signal-lamp circuit does not light up.	O/c in signal-lamp circuit	Check continuity of lamp filament and contact in lamp socket.	STAT
2. When signal is applied from tester, relay does not operate.	O/c is antenna valves	Check contacts in antenna-feeder connectors	
	O/c in one of the valves	Check voltages at the pins of the valves, according to table, article 5, section V and replace faulty component. Check current through relay winding. If current	

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No.	Nature of fault	Description of fault	Method of eliminating fault	Note		
			is low, check V_2 (6H3H) and diode ДПН-7 (or Д-102)			
2.	No current through relay winding	D/c of relay winding	Check relay winding with ohmmeter and replace relay of o/c			
3.	Relay does not operate	Poor contact in jack	Bend up jack spring slightly and clean contacts			
4.	Relay operates with no signal	Poor smoothing of 220V voltage arriving from source	Check smoothing of 220 voltage.			
		Jack s/c to earth	Check s/c of jack to earth with ohmmeter and eliminate s/c.			
<u>List of parts of radio receiver</u>						
No.	No. on circuit	State Stand. specif. drawing No.	Description and type	Main rating	Quantity	Note
1	2	3	4	5	6	7
1	R ₁	ГО.467.004	TV Resistor	BO-0.25-220 ohms-II	220 ohms	1
2	R ₂	"	"	BO-0.25- (27 to 31) ohms-II	ohms	1
						Selected during alignment
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1	2	3	4	5	6	7
11 R ₁₁	0.467.003 TV	Resistor	MIT-0.5-1.7 4.7 K-ohms 1			
12 R ₁₂			MIT-0.5-3 3 K-ohms 1			
13 R ₁₃	0.467.004 TV		BC-0.25-180 K-ohms III 180 K-ohms 1			
14 R ₁₄			BC-0.5-18 18 K-ohms 1			
15 R ₁₅			BC-0.25-470 470 K-ohms 1			
16 R ₁₆			BC-0.25- (1-3.3) (1 to 3.3) Selected during alignment			
17 R ₁₇			BC-0.25-470 470 K-ohms 1			
18 R ₁₈			BC-0.25- (1-3.3) (1 to 3.3) Selected during alignment			
19 R ₁₉			BC-0.5-43 43 K-ohms 1			
20 R ₂₀			BC-0.25-470 470 K-ohms 1			
21 R ₂₁	0.467.003 TV		MIT-0.5-3.3 3.3 K-ohms 1			
22 R ₂₂	EM5.634.014		wire-wound (35±0.5) ohms 35 ohms 1			
23 R ₂₃	EM5.634.013		wire-wound (25.5 ±0.5) ohms 25.5 ohms 1			
24 R ₂₄	0.467.004 TV		BC-0.25-75 75 ohms 1			
25 R ₂₅			BC-0.25- (22-36) (22 to 36) Selected during alignment			

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2	3	4	5	6	7
2H M100 024-52	Capacitor	KOT-1-1-20-50- obas. II	50 mF 1	In one	
2H0.460.022 TV		MBTL-2-200- 2x0.25-II-5	0.25mF 0.5	can with	C16
2C3.300.004 TV ₁	Type 6A11	valve			1
2C3.301.000 TV ₁	Type 6H13	valve			1
2C3.301.000 TV ₁	Type 6H3	valve			1
2P2.362.001 4TV	Silicon point contact diode, type A-102				1
2K3.062.017	Input tuned circuit coil				1
2K3.062.025	Anode tuned circuit coil				1
2K3.754.005	Radio frequency choke				1
2WY-55	Relay 30 - 11 E				1
2D0.364.002 4TV	Connector MCHHMB				1
2K3.604.005	Single pole receptacle				1
2K3.604.004	Jack				1
2P2.471.003	Electric Bell G33-2				1

Копировать

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Fig. 1. Complete RPH-56-II receiver with intra-fuselage antenna.

Fig. 2. Top view of receiver chassis.

Fig. 3. Schematic diagram of intra-fuselage antenna.
1. R.F. coil; 2. common; 3. tuning capacitor; 4. cavity; 5. frequency capacitor.

Fig. 4. Intra-fuselage antenna.

Fig. 5. Bottom view of receiver chassis.

Fig. 6. Block diagram of circuit for measuring receiver parameters.

1. signal generator, 100-7 (or P-10-10)
2. RPH-56-II receiver 3. v. 4. common-
5. electric bell relay 6. audio generator
7. P-21

Fig. 7. Block diagram of circuit for checking the tuning frequency of the intra-fuselage antenna.

1. RPH-48-2, RPH-56-II intra-fuselage antenna
2. RPH-56-II receiver

Fig. 8. Circuit diagram.

Form. No.	Circuit function	Destination	STAT
1	Common-	To	
2	+ 220 v	d.c.	
3	+ 27 v	network	
4	+ 27 v	To electric bell	

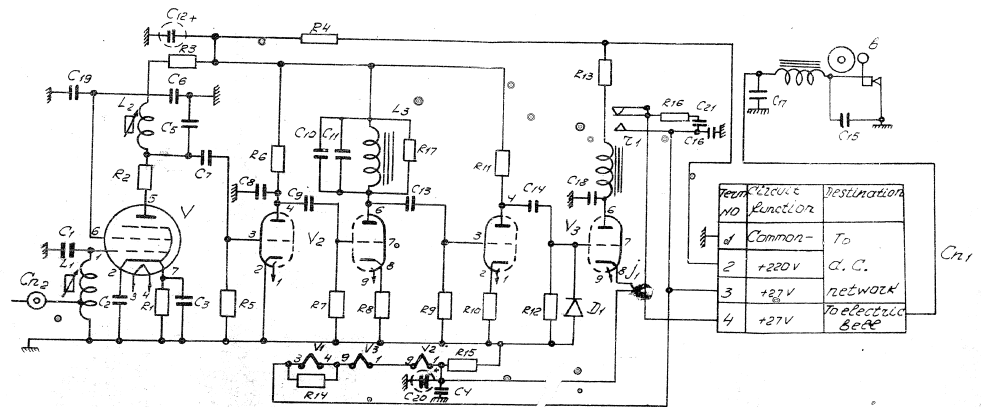
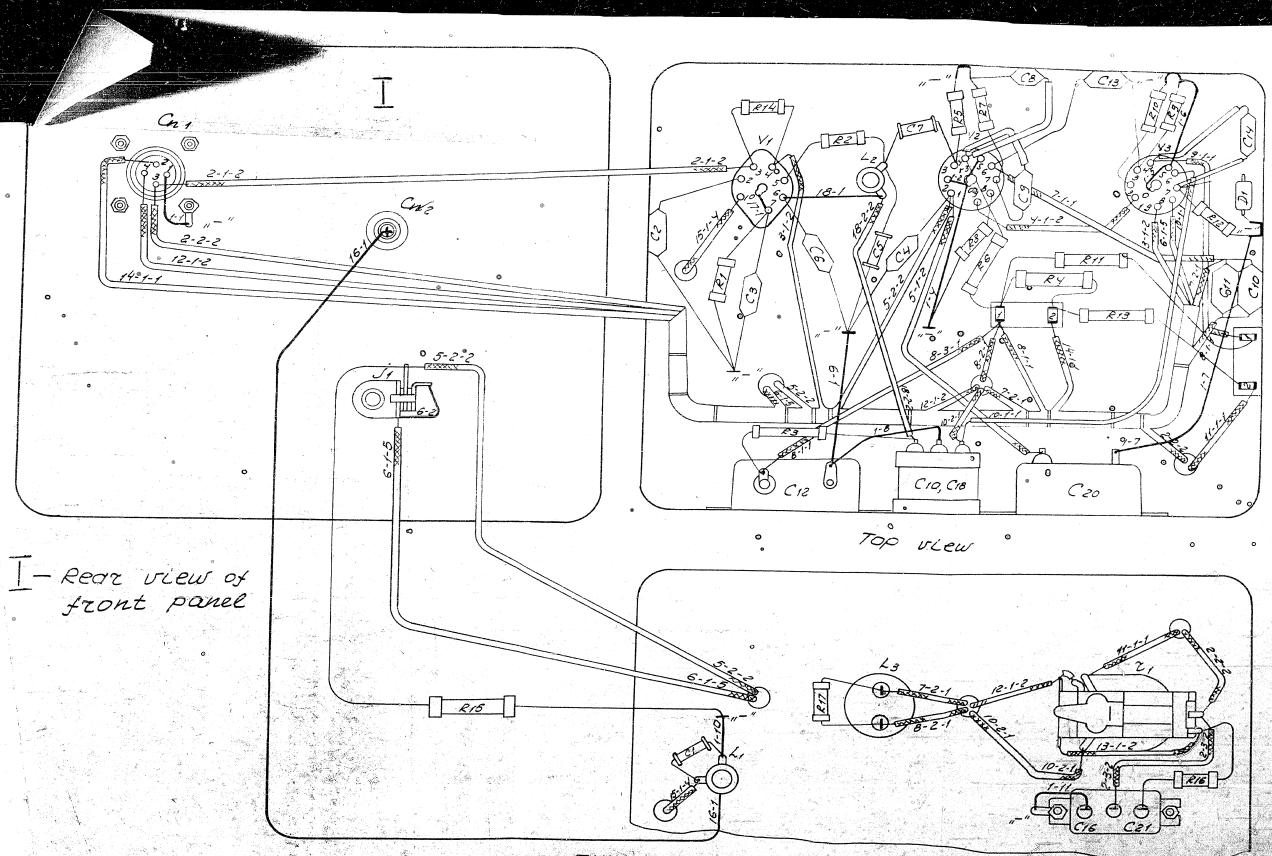
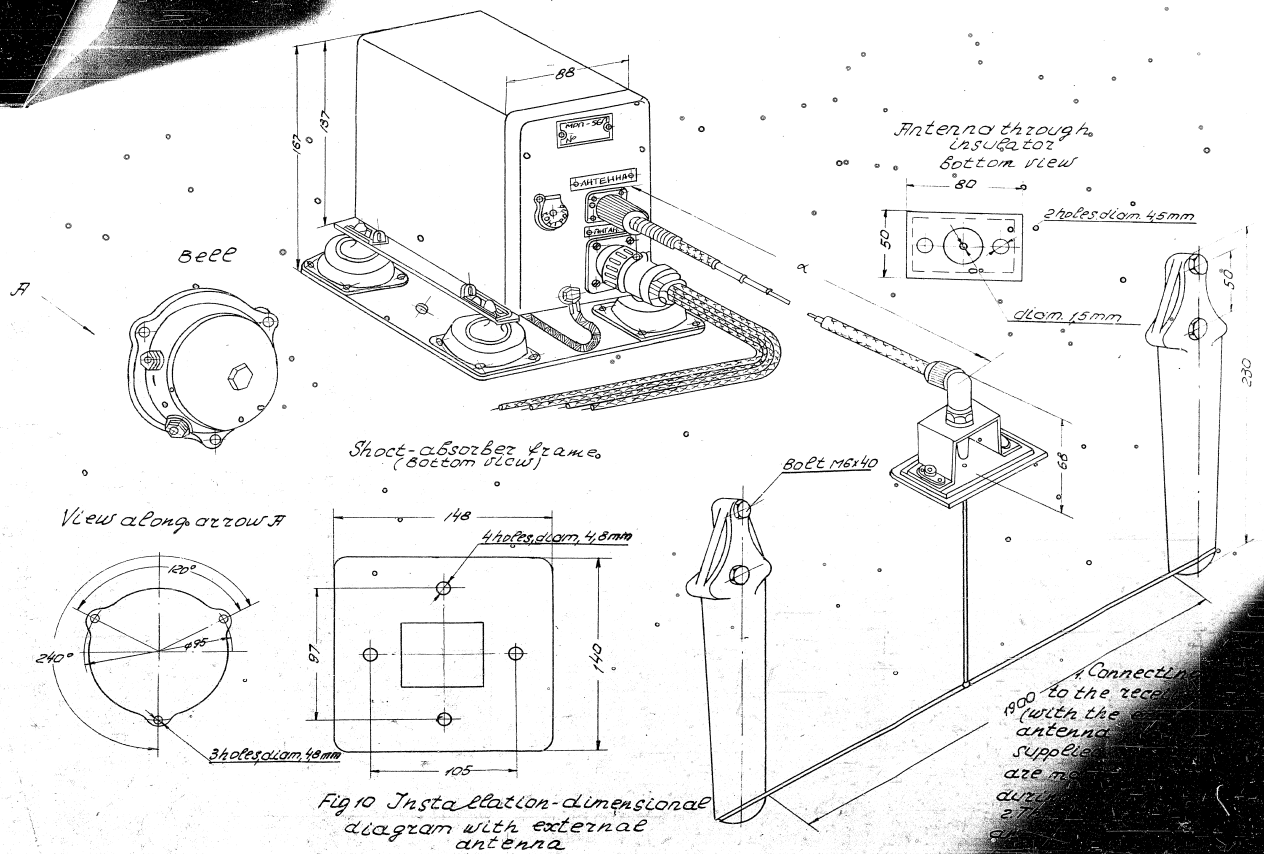


Fig 8 Circuit diagram



MPN-567 'receives'



MPN-56N receiver

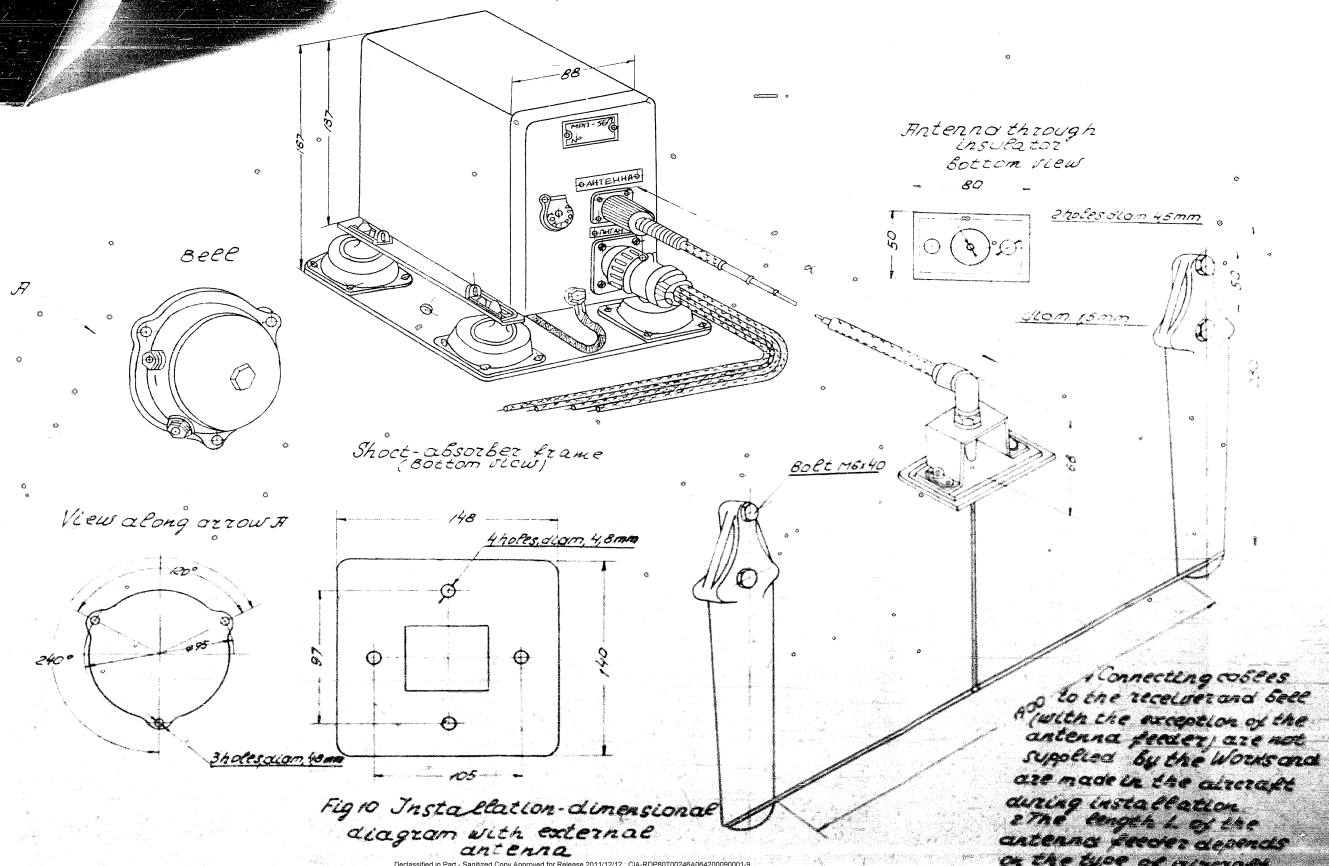
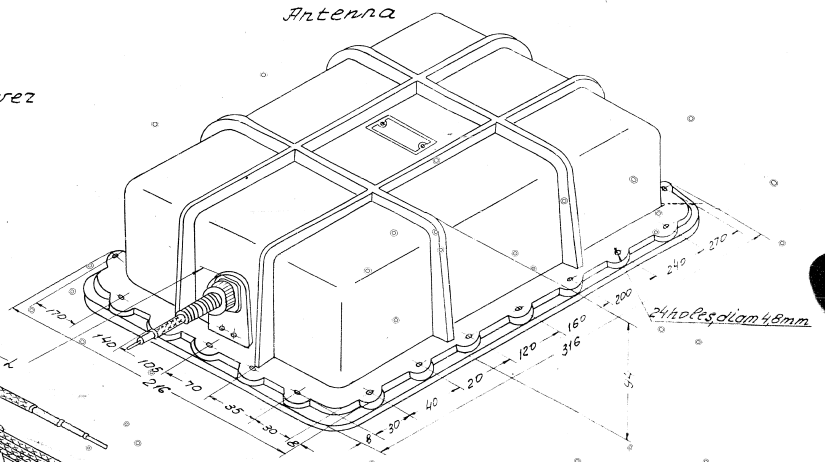
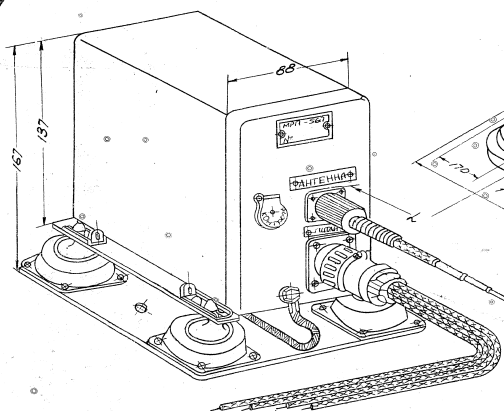


Fig 10 Installation-dimensional diagram with external antenna

MPN-567 receiver

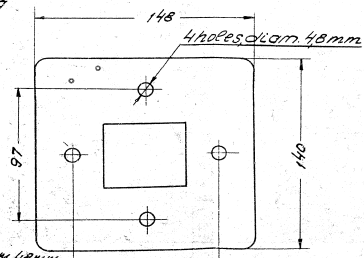
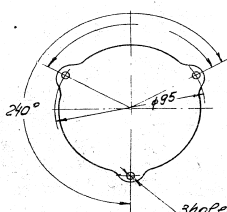
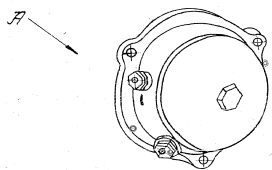
Antenna

Beel



Shock-absorber frame
(Bottom view)

View along arrow A



CAPACITOR-TYPE FUEL CONTENTS GAUGE

Model CSTC-200B

DESCRIPTION, OPERATION AND MAINTENANCE INSTRUCTIONS

- 1 -

. C O N T E N T S

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A. FUEL GAUGE DESCRIPTION

I. PURPOSE

The C9TC-260B capacitor-type fuel contents gauge is designed for:

- measuring the total quantity of fuel in the tanks of the left wing and right wing separately;
- measuring the fuel quantity in each tank group;
- automatic control of fuel usage;
- providing information on fuel reserve (one-hour flight and 15-minute flight);
- aircraft fuelling control.

General view of the C9TC-260B capacitor-type fuel contents gauge is shown in Fig. 1.



Fig. 1. General view of C9TC-260B capacitor-type fuel contents gauge components.

II. COMPLETING

The G3TC-260B fuel gauge system comprises the following units:

1. Two-pointer indicator 1
2. VTC-52-18 measuring units 2
3. EA-52-22 automatic control units.. 2
4. EA-52-23 fuelling automatic control unit 2
5. Capacitor type tank units with level switches... 12
6. III-8 wafer rotary switch .Q..... 1
7. III-1 remote-control selector switches..... 2
8. Spare electronic valves 6

III. FUEL GAUGE MAIN DATA

1. The fuel gauge system operates:

- a) at 115 volts $\pm 10\%$, 400 c.p.s. $\pm 5\%$ A.C.
and 27 Volts $\pm 10\%$ D.C.
- b) within the ambient air temperature range of -60° to $+50^{\circ}\text{C}$;
- c) at outside air pressure changing within the range of 760 to 44 mm.Hg. i.e. at altitudes from "0" to 20,000 m. above S.L.;
- d) at vibration within the frequency range of 25 to 80 c.p.s. and vibration overload of 2.5 g. for the measuring unit; automatic control units and remote-control switches;
1 g. for the tank units;
1.5 g. for the indicator and III-8 selector switch;
- e) at a relative air humidity from 30 to 98%.

2. When testing the fuel gauge with a test unit under normal conditions (at a temperature of $20 \pm 5^\circ\text{C}$, pressure of 760 mm.Hg., relative humidity of 30 to 80%, voltage of 115 V, 400 c.p.s.) the fuel gauge reading error does not exceed $\pm 2.0\%$ at the zero point; and $\pm 4.0\%$ of the nominal scale value at the other points of the scale.

3. An additional fuel gauge reading error for every 10°C temperature change from the normal temperature does not exceed $\pm 0.5\%$ of the indicator scale nominal value.

4. Level switch actuation error checked by a test stand does not exceed ± 100 litres for the tank units of the 2-nd tanks, and does not exceed ± 50 litres for the other tank units.

5. With voltage changing by $\pm 10\%$ and frequency changing by $\pm 5\%$ an additional fuel gauge reading error does not exceed $\pm 1\%$ from the nominal scale value.

6. Electric Capacitance of "Dry" Tank Units
(Initial Capacitance)

No.	Tank No. and Tank Unit No.	Tank unit electric capacitance in mmf.	Remarks
1	2E	1950	± 30
2	2L	1950	± 30
3	3	1950	± 30
4	5	1950	± 30
5	7	1950	± 30
6	8	1950	± 30
7		1950	± 30

Power consumed:
 operation current not more than 100 W
 alarm current not more than 50 W

3. When the fuel gauge automatic system is off, the indicator readings may vary by 35 kg. for a group of tanks and by 200 kg. for the total fuel quantity.

IV. PRINCIPLE OF OPERATION

1. Principle of Measuring System Operation

Measurement of the fuel quantity in the aircraft fuel tanks by means of the capacitor-type fuel contents gauge is based on measurement of tank unit electric capacitance which changes with fuel quantity.

The tank units mounted vertically in the aircraft fuel tanks consist of several concentric tubes with an air gap between them.

Since the dielectric constant of fuel depends only on fuel density which, in its turn, depends on temperature, the fuel gauge indications depend on both fuel volume and fuel density, i.e. they depend on the mass of fuel in the tanks.

The quantity of fuel in the tanks is indicated by measuring the varying capacitance of the tank units.

The tank unit capacitance is measured by an A.C. self-balancing bridge, one arm of which is a variable capacitor, i.e. the tank unit.

The capacitance bridge schematic diagram is shown in Fig. 2.

The bridge circuit is supplied from the transformer secondary winding while 115 V., 400 c.p.s. alternating current is supplied to the primary winding of the transformer.

The amplifier output voltage is supplied to the control winding of the 100-0-100 volt electric motor whose rotation causes the wiper of the voltage divider (R) to move to a position at which the difference between the potentials of the "J" and "K" points is zero again.

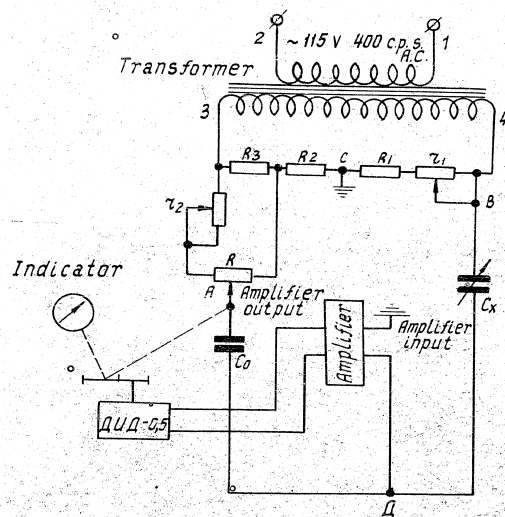


Fig.2. Capacitance bridge schematic diagram

The indicator pointer moves together with the voltage divider wiper.

When the initial capacitance of the tank unit is equal to zero $C_x \approx C_0$ (which corresponds to empty tanks), the bridge is adjusted by the rheostat (r_2) so that it becomes balanced when the voltage divider wiper (R) is in one extreme position and the indicator pointer reads zero.

When the tank unit capacitance changes to a value of $C_x \approx 2C_0$ (which corresponds to tanks filled up to capacity) the bridge is adjusted by the rheostat (r_2) so that it becomes balanced when the

- 7 -

voltage divider wiper (R) is in the other extreme position, and the indicator pointer is against the scale point corresponding to the quantity of fuel in the tanks.

Thus each position of the indicator pointer corresponds to a certain fuel quantity; the indicator can be calibrated in kgs of fuel.

In measuring the total quantity of fuel in the aircraft fuel tanks the measuring bridge schematic diagram remains unchanged.

2. Principle of Booster Pumps, Fuel Reserve Warning System and Fuelling Automatic Control Operation

Fuel usage, aircraft fuelling and fuel reserve warning system automatic control is accomplished by means of the alternating current bridge.

The automatic control system bridge schematic diagram is shown in Fig. 3.

The automatic system bridge consists of a variable inductor (L_v) built in the tank unit, constant inductor (L_p) and two coils (L_1 and L_2) of the transformer (Tp) secondary winding; the two coils being the other two arms of the bridge. 115 volt, 400 c.p.s. alternating current is supplied to the transformer (Tp) primary winding.

When the fuel in the tank reaches a certain level, an iron core is moved into the magnetic field of the level switch coil (L_s).

The positioning of the iron core in the coil field changes total resistance (Z) of the level switch coil (L_s); the bridge thus becomes unbalanced and at the R and C pick points of the bridge diagonal line there appears a potential difference which is conducted to the sensitive electromechanical relay (CR) winding through the 1M Ω germanium resistor connected in a bridge circuit.

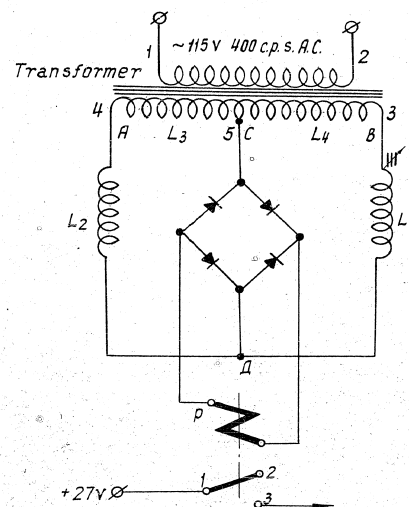


Fig.3. Automatic Control System Bridge Schematic Diagram

The relay is actuated and through its contacts energizes or de-energizes the booster pump relay winding and closes the indicator lights circuit.

V. ELECTRICAL SYSTEM AND OPERATION OF SEPARATE FUEL GAUGE ELEMENTS

The fuel gauge electrical system for the left and right wing consists of two independent circuits:

- 1) measuring and
- 2) automatic.

1). Electrical Circuit of Fuel Gauge Measuring System

Fuel quantity in the aircraft fuel tanks is measured in the left wing and in the right wing separately.

The measuring system electrical circuit for one wing is shown in Fig.4.

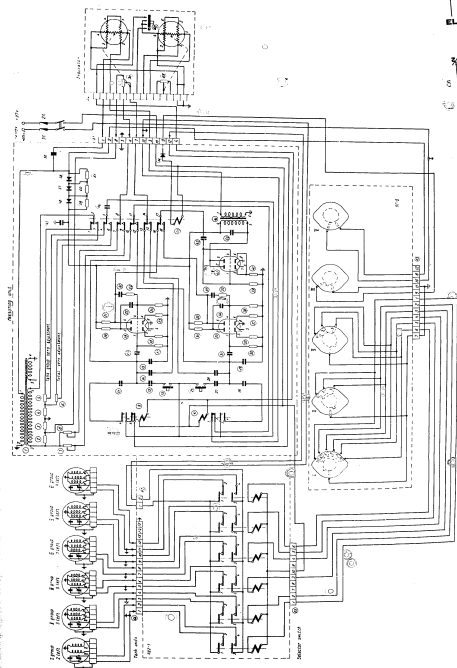
The circuit has two measurement channels. One channel is designed for measuring the total fuel quantity in the tanks, the other channel is for measuring the fuel quantity in a group of tanks.

When measuring the quantity of fuel in a tank group, the tank units are switched on in turn by means of the HP-8 wafer rotary switch; in this case the HP-8 switch knob is set to each of the six positions.

Switching over from measuring the fuel quantity in a tank group to measuring the total fuel quantity is also accomplished by means of the HP-8 selector switch; the switching over is effected by changing the group measurement elements for the elements measuring the total fuel quantity.

To test the fuel gauge for serviceability on the ground the "GROUP CHECK" and "TOTAL CHECK" buttons are provided on the measuring unit panel.

To test the fuel gauge for serviceability in flight use the button located on the indicator.



ELITE 5 10 15
FOR MEASURING
ROWE LINE

One-Wing Fuel Gauge Measuring System

Key to Fig. 4.

1 - Transformer; 2 - coil, 110 ohms; 3 - coil, 50 ohms; 4 - coil, 30 ohms; 5 - rheostat, 50 ohms;
 6 - rheostat, 30 ohms; 7 - rheostat, 500 ohms; 8 - rheostat, 400 ohms; 9 - PCM-2 relay; 10 - PCM-2
 relay; 11 - CTM capacitor, 4950 pf; 12 - capacitor, 1300 pf; 13 - button; 14 - CTM capacitor,
 1950 pf; 15 - CTM capacitor, 4300 pf; 16 - CTM capacitor, 10000 pf; 17 - MUT resistor, 510 kohms;
 18 - MUT resistor, 1.5 kohms; 19 - 6H9C valve; 20 - MUT resistor, 510 kohms; 21 - MUT resistor,
 220 kohms; 22 - CTM capacitor, 10000 pf; 23 - MUT resistor, 1 kohm; 24 - MUT resistor, 510 kohms;
 25 - button; 26 - CTM capacitor, 11700 pf; 27 - CTM capacitor, 4050 pf; 28 - CTM capacitor,
 11700 pf; 29 - CTM capacitor, 4300 pf; 30 - MUT resistor, 510 kohms; 31 - CTM capacitor,
 10000 pf; 32 - MUT resistor, 1.5 kohms; 33 - 6H9C valve; 34 - MUT resistor, 510 kohms;
 35 - MUT resistor, 220 kohms; 36 - CTM capacitor, 10000 pf; 37 - MUT resistor, 1 kohm; 38 - MUT
 resistor, 510 kohms; 39 - MUT resistor, 510 kohms; 40 - MUT resistor, 510 kohms; 41 - 6H9C valve;
 42 - CTM capacitor, 10000 pf; 43 - EPM -16-600 V capacitor, 10000 pf; 44 - transformer; 45 -
 TUBESOLA relay; 46 - MEIN capacitor, 1 mf; 47 - MEIN capacitor, 4 mf; 48 - MUT germanium diode;
 50 - MEIN -0.25-500 V capacitor, 0.25 pf; 51 - MP82V12H11 plug connector; 52 - CTM capacitor,
 51-510 pf; 53 - MUT resistor, 2-30 kohms; 54 - CTM capacitor, 51-510 pf; 55 - MUT resistor,
 2-30 kohms; 56 - MUT germanium diode; 57 - 47% germanium diode; 58 - 47% germanium diode;
 59 - MUT resistor, 100 kohms; 60 - MUT resistor, 100 kohms; 61 - MUT resistor, 100 kohms;
 63 - MP82H12H11 plug connector; 64 - MP82H12H11 plug connector; 65 - MP82H10H11 plug connector;
 66 - MP82H15H14 plug connector; 67 - MP82H12H11 plug connector; 68 - button; 69 - voltage
 divider, 200 ohms; 70 - voltage divider, 200 ohms.

2. Electrical Circuit of Fuel Gauge Automatic System

Diagram of one-wing fuel usage automatic control system is given in Fig.5.

The aircraft fuelling automatic control system diagram is shown in Fig.6.

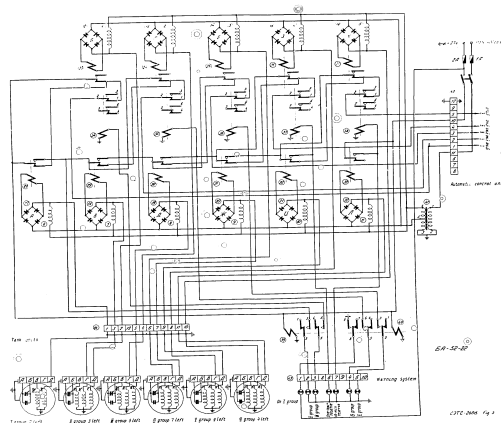


Fig.5. One-Wing Fuel Usage Automatic Control System Wiring Diagram

1-11 - Induction coils; 12-22 - A7I germanium diode; 23-33 - electromagnetic relay; 34-39 - TR52HA relay; 40 - TR53HA relay; 41 - transformer; 43 - MP32V12HMI plug connector; 44 - MP32V12HII plug connector; 45 - MP32V10HII plug connector.

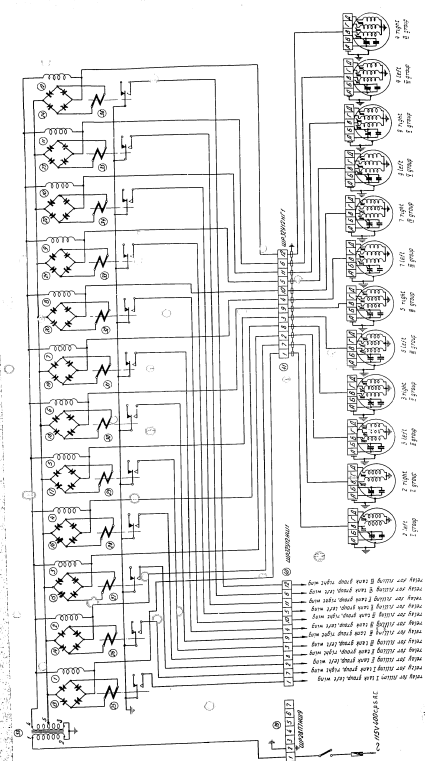


Fig. 6. Aircraft Fueling Automatic Control System Wiring Diagram

1-12 - Induction coils; 13-24 - 47F germanium diode; 25-36 - electromagnetic relay; 36 - transformer; 39 - MP28V7HM9 plug connector; 40 - MP28V72HM plug connector; 41 - MP28V72HM plug connector;

The fuel gauge automatic system consists of separate A.C. bridges, whose principles of operation are described in Section IV.

Fuel usage is automatically controlled for the left wing and right wing separately, but the electrical systems of the fuel usage automatic control units for both the left and right wing are the same.

Automatic control of fuelling is effected through the single automatic control unit for both wings.

Each BA-52-22 fuel usage automatic control unit consists of 11 bridges, transformer, electromagnetic relays.

The BA-52-23 fuelling automatic control unit consists of 12 bridges, transformer and electromagnetic relay.

VI. DESIGN OF SEPARATE ELEMENTS OF FUEL GAUGE SET

I. TANK UNITS

General view of the tank unit is shown in Fig.7.



ELITE
10
ROWE I
FOR MEASURING
3/4 1 1 1/2

6370-2400-1197

Fig.7. Tank Unit General View

The tank unit is an assembly of concentric profiled and non-profiled tubes. The tank tubes are profiled in order to obtain equal amounts of electric capacitance per volume unit.

Sections of the tubes as well as their number and clearance between them are determined by the curve illustrating the fuel volume dependence on fuel level, i.e. $V = f(H)$.

Number of tubes in tank units varies from 4 to 5.

Clearance between the tubes is 1.5 mm.

The inner tube (35 mm. dia.) of the tank unit houses a level switch. Since the electric capacitance of "dry" tank units varies for different groups, then to obtain the zero reading on the indicator scale all the groups of the tank units must have equal capacitance with the fuel system empty. Initial capacitance of the tank unit groups is equalized by means of the constant capacitance trim condensers located in the tank units heads.

2. MEASURING UNIT

Figs. 8 and 9 illustrate the measuring unit enclosed in the housing and with the housing removed.

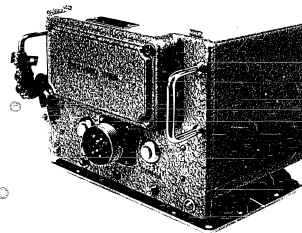


Fig. 8. Measuring Unit in Its Housing

- 16 -

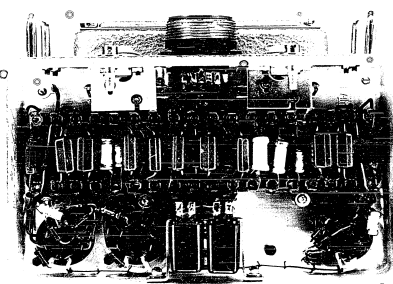
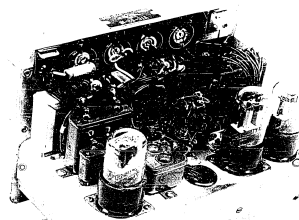


Fig. 9. Measuring Unit with the Housing Removed

- 17 -

All the components of the measuring unit are located on the chassis inner and outer sides (Fig. 9) and on the inner side of the front panel.

Located on the face side of the front panel (Fig. 8) are four rheostats for adjusting the zero and maximum indications of the scale, two "GROUP TEST" and "TOTAL TEST" buttons, and 12-pin plug connector for connection to the selector switch and indicator.

Attached to the same panel is the cable grounding the measuring unit to the aircraft structure.

Contact resistance between the measuring unit casing and the end of the grounding cable should not exceed 1400 microhms.

3. AUTOMATIC CONTROL UNIT

The automatic control units in the housing and with the housing removed are shown in Figs. 10, 11, 12.

Design of all the three automatic control units is similar, the only difference being in the number of the automatic control bridges and in the electrical circuit.

All the automatic control unit components are located on the chassis and on the inner side of the front panel.

Located on the outer side of the front panel are plug connectors which serve to connect the automatic control units to the fuel gauge circuit and for grounding the unit to the aircraft structure.

4. INDICATOR

The indicator in its casing and with the casing removed is shown in Fig. 13.

The indicator consists of two independent systems incorporated in a single casing. Both systems of the indicator are similar. The indicator kinematic diagram is shown in Fig. 14.

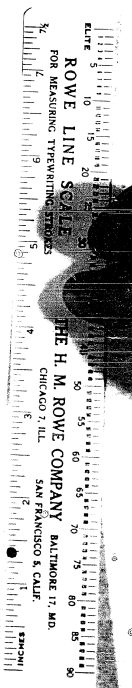
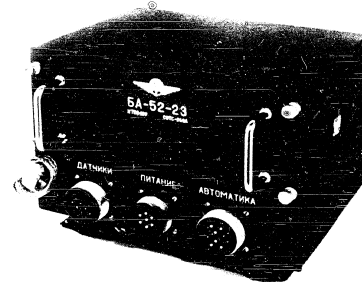


Fig.10. Automatic Control Unit in its Housing.

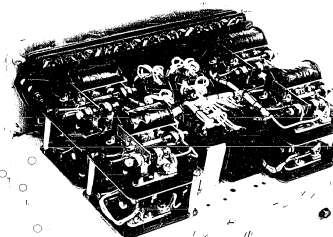


Fig.11. BA-52-22 Automatic Control Unit with the Housing Removed

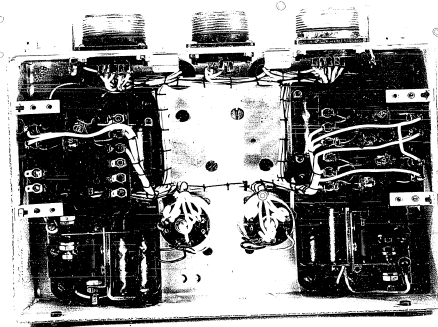
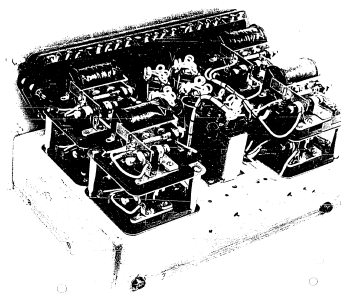


Fig. 12. BA-52-28 Automatic Control Unit with the Housing Removed

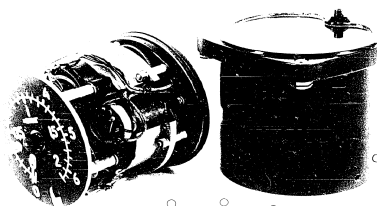


Fig. 13. Indicator in its Casing and with the Casing Removed.

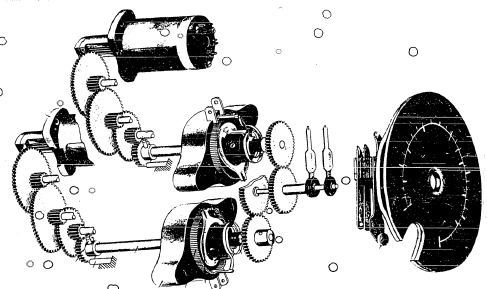


Fig. 14. Indicator Kinematic Diagram

Each of the systems (Fig. 14) consists of the following main components: AMM-0,5 low inertia electromotor, voltage divider in a special housing, the voltage divider resistance being 200 ohms, reduction gear with the gear ratio 1:500, voltage divider wiper and indicator pointers.

The voltage divider wiper is secured to the outlet shaft of the reduction gear. Rotation of the reduction gear shaft is transmitted to the pointer through a pair of idle gears.

The conductor carrying current to the voltage divider wiper is made in the form of a spring.

The AMM-0,5 is an induction asynchronous electric motor.

The indicator has no return spring and, therefore, with power supply off or any malfunction in the circuit the indicator pointer may be at any point of the scale.

A test button is provided in the indicator to check the circuit for condition.

The indicator is connected to the fuel gauge circuit through a 14-pin plug connector.

The indicator scale angle is 300° with a permissible tolerance of $\pm 20'$.

The dial carries two scales.

The outer scale is used for indicating the total fuel quantity, and the inner scale - for indicating the quantity of fuel in a tank group.

The indicator pointers are marked with letters H (Right) and L (Left). The letters correspond to the wing (right or left) in which the fuel quantity is measured.

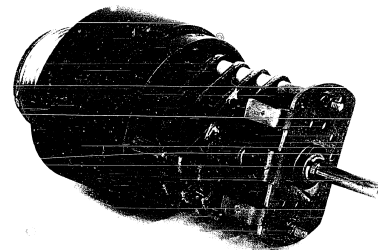
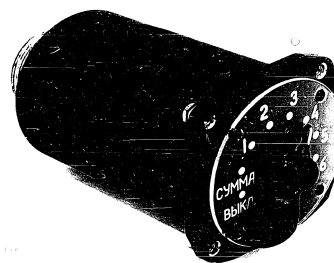


Fig. 15. ИТ-8 Selector Switch in its Casing and with the Casing Removed

- 24 -

5. M-8 SELECTOR SWITCH

The M-8 selector switch enclosed in its casing and with the casing removed is shown in Fig. 15.

The selector switch can be set in eight fixed positions: "OFF", "TOTAL", "1", "2", "3", "4", "5" and "6", which are painted on the dial with luminous material.

6. REMOTE-CONTROL SELECTOR SWITCH

The M2-I remote-control selector switch in its casing is shown in Fig. 16.

The M2-I selector switch incorporates six PCM-1 electromagnetic relays installed in a single casing.

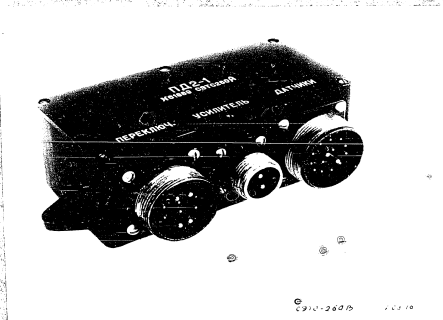


Fig. 16. M2-I remote control switch in its housing.

The MM2-I selector switch is connected to the fuel gauge circuit through 10-pin and 15-pin plug connectors.

Power is supplied to the selector switch through a 2-pin plug connector.

B. FUEL GAUGE OPERATION AND MAINTENANCE INSTRUCTIONS

VII. INSTRUCTIONS FOR FUEL GAUGE INSTALLATION IN AIRCRAFT

1. Wiring and Checking the External Circuit

a) The external circuit should be wired in the aircraft in accordance with the external connections diagram shown in Fig. 17.

PK-6J wire, EMBWIS wire of 0.35 to 0.5 mm², EMBW wire of 0.35-0.5 mm² are used for wiring the fuel gauge system in the aircraft. The wire shieldings must be securely grounded.

The wire shieldings should have no longitudinal cracks and must have secure contacts in the wires connection points.

The wires, whose shieldings are grounded, are inserted together with their shieldings in the plug connectors.

The wire shieldings must be electrically connected to the plug connector body.

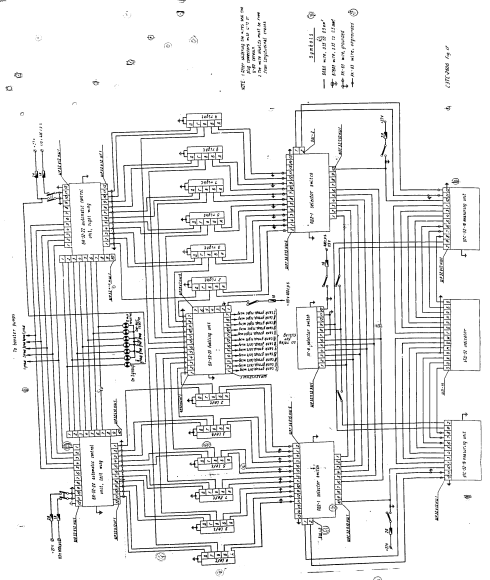
See that the wire insulation is not damaged.

At a temperature from -60° to +50°C and relative humidity of 30 to 90% the external wiring insulation resistance (before connecting to units) should be not less than 10 megs.

The access doors through which the wiring is laid in the aircraft must be water-proof.

After the connection wiring has been mounted, it must be checked for conformity with the external connections and insulation resistance diagram.

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ROWE LINE FOR MEASURING TYPE

48.17

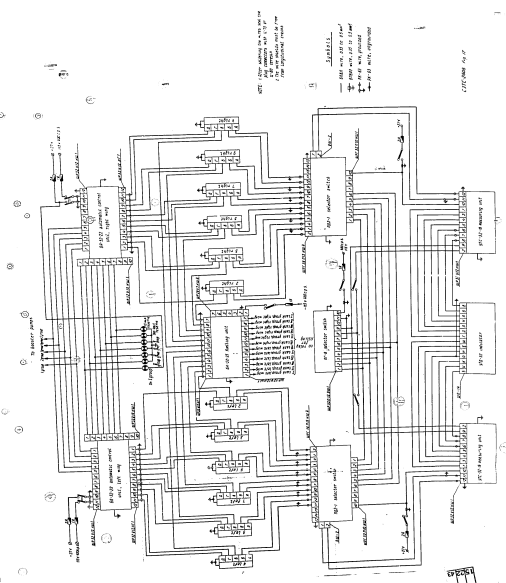


Fig. 17 COTC-260B Fuel Gauge Set External Connection Wiring Diagram

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b) Insulation resistance test.

The connection wiring insulation resistance is tested by a megger with 500 volts applied.

2. Checking Fuel Gauge Set Components Prior to Installation in Aircraft

Prior to installing the fuel gauge set in the aircraft test all its components for insulation resistance, check the measuring system for serviceability and the automatic system for proper functioning.

a) Insulation resistance test at normal temperature and relative humidity of 30 to 80%.

The indicator, HP-8 selector switch and HM2-I remote control selector switch insulation resistance is tested by a megger with 500 volts applied.

b) Testing the fuel gauge set for serviceability.

After the test of the insulation resistance has yielded satisfactory results, connect the fuel gauge in the circuit according to the external connections diagram (Fig. 17), and 2-3 minutes after it is energized (the time required for valves warming up) check the circuit for condition and the power supply circuit for continuity.

To check the circuit for condition and serviceability when measuring the total fuel quantity, set the HP-8 selector switch to the "TOTAL" position and press the "TOTAL TEST" button on the front panel of the measuring unit.

If the indicator pointer moves 1/2 to 3/4 of the scale range to the right with the button pressed, this indicates that the set circuit is serviceable and energized.

When testing the system for proper operation when measuring the

quantity of fuel in each group of tanks, move the switch knob from the "TOTAL" position to the positions corresponding to either of six groups in due sequence. When turning the selector switch for checking either of the groups, do it in the same manner as in the totalizing system, i.e. by pressing the "TEST" button on the measuring unit.

If the indicator pointer moves $1/2$ to $3/4$ of the scale range to the right, this will indicate that the system is serviceable and energized.

c) Testing automatic system for proper operation

The automatic system is tested for proper operation at 103.5 and 126.5 volts by means of the YUA-260 test unit in accordance with the instructions furnished with the unit.

If the results of the units' test are satisfactory, the units are permitted to be installed in aircraft.

3. Fuel Gauge Installation in Aircraft

The fuel gauge set must be installed in aircraft in accordance with the external connections diagram shown in Fig. 17.

The fuel gauge tank units are installed in the aircraft fuel tanks in accordance with their marking. The tank units are attached by means of four bolts inserted through the holes in the tank unit flange and fuel tank opening flange. A rubber kerosene-proof sealing is placed between the tank opening flange and tank unit flange.

The indicators and III-8 selector switch are installed on the shock-mounted instrument panel and secured with four screws each.

The YIC-52-18 measuring units, BA-52-22 and BA-52-23 automatic control units are installed in the fuselage centre section and secured with four bolts inserted either through the shock mounts on the measuring unit attachment plate, or through the four holes in the automatic control unit attachment plate.

4. Checking and Adjusting Fuel Gauge Set After Installing it in Aircraft

A. Check and adjustment of fuel gauge before fuelling the aircraft

Prior to the check turn on power supply and make the check 2-3 minutes after the system is energized.

a) Testing fuel gauge for serviceability

Test the fuel gauge for serviceability in accordance with para. 2, b of this section.

b) Checking and adjusting the indicator pointer zero position when measuring fuel quantity in tank group.

To check and adjust the indicator pointer zero position set the III-8 selector switch to the position corresponding to the group of tank in which the fuel quantity is to be measured.

If after this the indicator readings are off the permissible limits (± 40 kg), adjust the fuel gauge by the tank group zero adjustment rheostat. To do this remove the seal from "ZERO SETTING" cover, unscrew the two screws attaching it to the front panel of the measuring unit, remove the cover and, turning the rheostat labelled "TANK GROUP ZERO", set the indicator pointer against zero point, permissible deviation being not more than ± 40 kg.

NOTE: 1. To prevent an error that may arise from the automatic system influence upon the measuring system check and adjust the latter with all the set components connected. When operation of the booster pumps is not permissible, they may be cut off by disconnecting the automatic control system plug connectors labelled "AUTOMATIC".

2. If the indicator pointer is below zero, turn the rheostat clockwise and when the pointer is above the zero, turn the rheostat counterclockwise.

3. The zero adjustment is accomplished for one of the groups and the check is made for all the six groups. If the indicator does not read zero within the permissible limits for one or several groups, perform adjustment till the indications for all six groups are within the limit.

c) Checking and adjusting the indicator pointer zero position when measuring total fuel quantity

To check the fuel indicator zero reading set the ПЗ-8 selector switch to the "Total" position.

If the indicator readings are beyond the permissible limit (± 128 kg), adjust the fuel gauge by the total zero adjustment rheostat.

Do it in a manner similar to that of tank group zero reading adjustment but in this case turn the rheostat labelled "Total zero".

d) Testing the fuel gauge automatic system

The automatic system of the fuel gauge is tested by means of the test unit.

VHA-260

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After the fuel gauge is installed in the aircraft the check by means of the VHA-260 test unit implies testing of the automatic control system bridges for proper operation, check of the connection wiring for continuity and the fuel level switches for proper functioning.

Test the automatic control system by means of the VHA-260 test unit in accordance with the instructions furnished with the unit.

Proper condition of the fuel level switch coil is determined by the VHA-260 test unit indicator.

If it is found during the test that the level switch is faulty, replace the tank unit with the defective level switch by a new tank unit of the same calibration and for the same tank.

B. CHECK AND ADJUSTMENT OF THE SET AFTER THE SYSTEM IS FILLED WITH FUEL

Before closing switch on the power supply and perform the check 2-3 minutes after the set is energized.

a) Checking and adjusting the tank group fuel quantity indicator reading

Set the III-6 selector switch knob against the "1" mark which will correspond to measuring the quantity of fuel in the 1-st tank group.

In this case the indicator pointer should read the quantity of fuel in this tank group.

The fuel quantity in volume units is determined by the fueller counting reading multiplied by the fuel density value.

If the fuel gauge indicator reading is off the permissible limit,

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readjust the fuel gauge by the "TANK GROUP MAX." rheostat for the quantity of fuel filled.

For this purpose remove the "ZERO SETTING" cover and adjust the fuel following the procedure described in para. A-b of this section. But in this case turn the "TANK GROUP MAX" rheostat.

Adjust the fuel gauge so as to make the indicator readings correspond to the quantity of fuel in the group tanks, permissible deviation being not more than $\pm 4\%$ (80 kg).

After this, switch on each tank group in sequence, read the fuel quantity on the indicator dial, and, if the reading differs from the fuel quantity in the group tanks, with the permissible deviation of 80 kg. taken into account, adjust the fuel gauge with the "TANK GROUP MAX" rheostat so as to bring the indications for each group to within the permissible limits.

Actual quantity of fuel in each tank group is determined by the formula:

$$V = V \cdot p$$

where V - volume indicated by the fueller counter;

p - fuel density at a given moment.

Set the switch knob against the "6" mark; this position will correspond to measuring the quantity of fuel in the last tank group according to the fuel usage sequence. Then read the fuel quantity on the indicator dial. Divide this value by the fuel density value and record the volume obtained in the fuel gauge general certificate.

Bear in mind that the tanks of this group must be filled up to capacity.

b) Checking and adjusting the total fuel quantity indicator reading

To check the total fuel quantity indicator reading set the selector switch knob against the "TOTAL" mark. In this case the indicator pointer should read the scale point corresponding to the total quantity of fuel in all the six groups with permissible deviation of $\pm 4\%$ (± 256 kg).

If the indicator readings are beyond the permissible limit, readjust the fuel gauge by the "TOTAL MAX" adjustment rheostat.

The adjustment is accomplished in a manner similar to that of the tank group maximum adjustment, but at this turn the rheostat labelled "TOTAL MAX".

After adjusting the measuring unit attach the "ZERO SETTING" cover and seal it with a seal of the organization which accomplished the fuel gauge adjustment.

The above described adjustment is accomplished after the fuel gauge has been installed on the aircraft or during operation, after an overhaul or replacement of the measuring units

In operation it is advisable to check the fuel quantity readings in the following manner:

c) Checking the tank group fuel quantity indicator reading

Set the HP-S selector switch knob against the "6" mark. This done, the indicator pointer should read the quantity of fuel filled in this tank group equal to $V \cdot \rho$

where V - fuel volume registered in the general certificate
 ρ - fuel density.

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In this case the 6-th group tanks must be filled up to capacity.

If the indicator reading does not correspond to the quantity of fuel in the tanks, readjust the fuel gauge by means of the "TANK GROUP" rheostat.

Then switching over the selector switch to each tank group in due sequence check the indication of the quantity of fuel in each fuel tank group. The sum of the indications is equal to the total fuel quantity for the given engine.

d) Checking the total fuel quantity indicator reading

Set the HT-6 selector switch knob against the "TOTAL" mark and check the indicator pointer position for reading the total quantity of fuel in all the six groups. If the reading does not correspond to the total fuel quantity, readjust the fuel gauge by the "TOTAL" rheostat.

This check precludes any additional error that may be caused by changing the fuel grade or replacing a fuel gauge act component.

VIII. OPERATION AND MAINTENANCE INSTRUCTIONS

1. Prior to every flight check the fuel gauge for serviceability. Effect zero adjustment and proper operation of the automatic system.
2. In flight periodically check the fuel gauge for proper operation. For this purpose press the indicator button. If the system operates properly, the indicator pointer will move towards the zero mark of the scale.
3. During operation, it is allowed to replace the valves in the measuring unit. To replace the valves in the measuring unit, open the valves.

For this purpose remove the seal from the measuring unit, unscrew the four bolts attaching the measuring unit to the housing and using the two handles located on the measuring unit front panel, remove the measuring unit from its housing.

Replace the valves. Close and seal the measuring unit with a seal of the organization which replaced the valves.

After replacing the valves check the fuel gauge for serviceability.

IX. SERVICE TROUBLES, THEIR CAUSES AND REMEDY

Outlined below are the most probable troubles of the fuel gauge set, their causes and remedy.

Nos.	Trouble	Cause	Check and remedy
1	2	3	4
1.	Indicator pointer is pressed against left stop.	a) Tank unit circuit is broken. b) Tank units external connection circuit is broken. c) Measuring unit internal circuit leading to tank units is broken. d) No contact on PCM-2 relay measuring unit. e) No contact on PCM-1 relay located in remote-control switch.	a) Check tank units. Remedy defect. b) Check connection circuit, repair defective circuit. c) Replace measuring unit. d) Replace measuring unit. e) Replace faulty remote-control switch.

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- | 1 | 2 | 3 | 4 |
|--|---|--|---|
| | | f) No power supply of 27 V. | r) Repair D.C. circuit. |
| | | g) Measuring unit 6H9C valve grid lead is grounded | g) Replace measuring unit. |
| | | h) No contact between tank unit tubes and plug connector outlet pins. | h) Check contact for security. Replace tank unit. |
| | | i) Connection wire leading to 6H9C valve grid is grounded. | i) Check circuit and remedy defect. |
| 2. Indicator pointer is beyond maximum point of scale. | a) Tank unit tubes are short-circuited. | a) Switching on each tank unit in turn, find out a faulty tank unit or a group of tank units. Remove faulty tank unit from tank. Using a megger, test insulation resistance between tubes and between each tube and aircraft structure. If resistance is less than 100 megohms, wash defective tank unit with clean fuel and dry it. | |

- | 1 | 2 | 3 | 4 |
|---|---|---|---|
| | | | Then check insulation resistance once more. |
| | | | If it is not less than 100 megs, install tank unit in place. If insulation resistance is less than 100 megs, replace tank unit. |
| | | b) Constant capacitance arm of measuring bridge is broken. | b) Replace measuring unit. |
| With selector switch in "TOTAL" position, indicator pointer is beyond maximum point of scale. | a) TR396 III relay D.C. supply circuit is broken. | a) Repair broken circuit. | |
| | b) TR396 III relay fails to operate. | b) Replace measuring unit. | |
| Indicator pointer does not move. | a) A.C. supply circuit is broken. | a) Check circuit with a tester. Repair circuit. | |
| | b) 6N93 and 6N81 valves of measuring unit are faulty. | b) Replace valves. After replacing valves check set for proper functioning by pressing "TEST" button on the front panel of the measuring unit. With "TEST" button pressed, indicator should move through 1/3 to 2/3 of scale range. With button | |

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1 2 3

4. Poor sensitivity of indicator.

a) Resistance of insulation between tank unit tubes and aircraft structure is less than 100 megs.

released, indicator should return to normal position.

a) Switching on tank unit in turn, find out tank unit on which tank. Check insulation resistance between tank and between tubes and aircraft structure. If resistance is less than 10 megs, dry unit and check resistance again. If still low, dry unit. Check for sense of water.

b) 6H9C and 6H8C valves emission is lost.

b) Replace valves.

c) Connection circuit insulation resistance is less than 10 megs. Using a megohmmeter, check insulation resistance. If less than 10 megs, remedy defective insulation. Resistance should not be less than 100 megs.

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1	2	3	4
		d) Output trans- former primary winding turns are short- -circuited.	e) Replace measuring unit.
6. With tanks empty indicator pointer indicates a quantity of fuel in tanks.	Resistance of circuit of tank unit insula- tion is low.		Disconnect all com- ponent units of set and check circuit insulation resistance. If insulation resist- ance is low, repair circuit. Switching on tank units in turn, find out a defective tank unit or a group of tank units. Re- move defective tank unit from tank. Dry it and then check resistance of its insulation again. If it is below 100 mega- ohms, replace tank unit. Check plug connector contacts and contact between shielding and aircraft struc- ture for security. Remedy defect.
7. When tank unit or wire is touched, indi- cator pointer begins moving.	Poor contact in plug connector. Grounding is not secure.		

1	2	3	4
8. Warning light does not go on.	a) Lamp has burnt out.	a) Replace lamp.	
	b) D.C. supply circuit is broken.	b) Repair circuit.	
	c) A.C. supply circuit is broken.	c) Repair circuit.	
	d) TKB56 III relay is faulty.	d) Replace automatic control unit.	
	e) Electromagnetic relay is faulty.	e) Replace automatic control unit.	

- NOTE:**
1. When checking the circuit insulation resistance, disconnect all the component units of the set.
 2. When checking the tank unit insulation resistance, remove the tank units from the tanks.

X. GENERAL INSTRUCTIONS

It is not recommended to disassemble the units, as their elements are very complex, they are thoroughly adjusted and tested at the manufacturing plant. External defects may be eliminated by the unit engineer's order only.

In cases of emergency, separate component units of the set may be opened. In this case the set component units may be repaired.

After repair and prior to installation on aircraft check the set component units for insulation resistance, serviceability, zero adjustment and proper operation of the automatic control system.

Check the units following the procedure described in Section VII.

XI. PERIODIC MAINTENANCE OPERATIONS

Once every six months wash the tank units, test insulation resistance of the connecting lines, check serviceability of the set, check the 6-th fuel tank group indication for conformity with the values specified in the general certificate, test the automatic system for proper operation.

Wash the tank units in the following manner: remove the screws attaching the bottom to the tank unit, immerse the tank unit several times into gasoline of fuel of T-1 grade; then allow it to dry for 30 minutes and install the bottom in place.

After this, check resistance of the tank units insulation and initial capacitance.

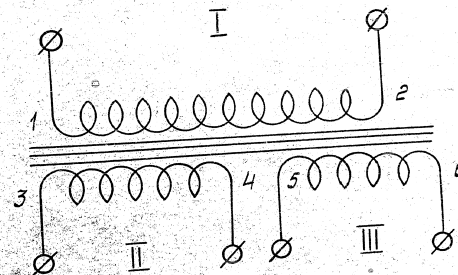
XII. STORAGE INSTRUCTIONS

CSTC-260B Capacitor-type fuel contents gauges must be stored in a dry room, at normal temperature, in a special tare with separate section for each component unit of the set or in the Manufacturer's packing without checking it for two years from the day the fuel gauge was accepted by the customer.

XIII. TRANSFORMERS WINDING DATA

Measuring Unit Transformer Data

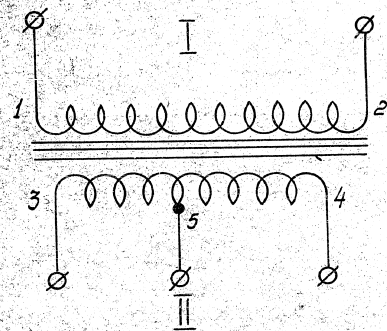
(see diagram Fig.4, ref.No.1)



1. Winding I - 115 V; wire HGB-2 ϕ 0.25
number of turns - 405
2. Winding II - 22 V; wire HGB-2 ϕ 0.25
number of turns - 84
3. Winding III - 6.3 V; wire HGB-2 ϕ 0.93
number of turns - 23.

Measuring Unit Transformers Data

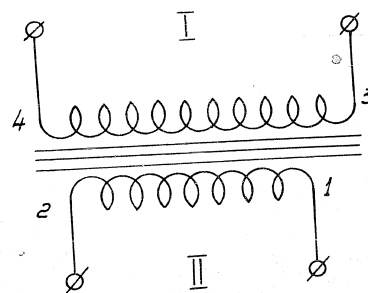
(See diagram Fig. 4, ref.No.44)



Winding I; wire ПЭЖНО $\varnothing$ 0.12
 number of turns - 2000.
 Winding II; wire ПЭВ-2 $\varnothing$ 0.15
 number of turns - 450.

Automatic Control Unit Transformer Data

(See diagrams Fig. 4, 5 ref. Nos. 41 and 38)



1. Winding I; wire H3B ϕ 0.29
number of turns - 548.
2. Winding II; wire H3B-1 ϕ 0.51
number of turns - 122
with the centre tapping from the 61-st turn of winding.

COPY No:

GPK - 48 INDICATOR

PRAGUE 1958

 DIRECTIONAL GYRO GPK-48

Purpose.

The electric directional gyro /fig.1/ GPK-48 is used for leading the airplane according to the given course and for precise execution of the aircrafts turns.

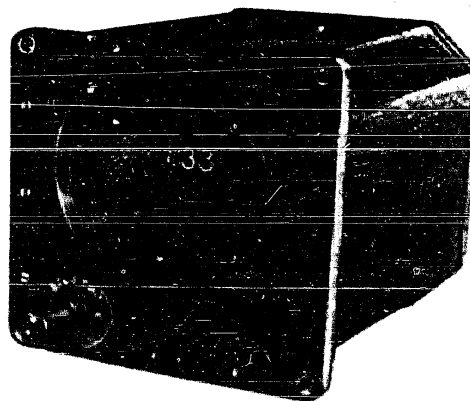


Fig.1. Outside view of the directional gyro GPK-48.

Principles of the function of the directional gyro
 GPK-48

The principles of the function of the electric directional gyro GPK-48 are based on the property of a gyroscope to move freely around three axes and to maintain the given position of the proper axis of rotation unchanged in space. The gyroscope rotor which is itself a sensitive element of the directional gyro GPK-48 is provided with a horizontal axle.

To make the function of the directional gyro clear, see Fig.2, which shows the scheme of an airplane equipped with the directional gyro, free to move around three axes, and its proper axis of rotation in the horizontal position. A card graduated into 360 degrees is set to the outer frame of the gyroscope.

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The graduation of the card from 0° to 360° corresponds with the axle of the gyroscope roter.

Situation I. The symmetrical axis of the airplane is perpendicular to the axis of the roter. In this case the instrument shows the course 90° . If the axis of the roter will not change its position, with regard to the ground, the reading remains the same and the course of the airplane will be kept unchanged.

Situation II. The airplane has changed its course by turning some degrees to the right. Because the gyroscope maintains the position of the proper axis of rotation, the turn of the airplane will not change the position of the axis of the gyroscope roter. When the angle between the symmetrical axis of the airplane and the axis of the gyroscope roter changes, there changes also the reading of the instrument. The difference between the previous reading and the now one determines the value of the change in course, i.e. the angular value of turn of airplane.

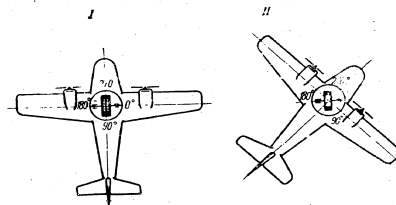


Fig.2. Use of gyro-compass for setting course.

By means of the directional gyre the given course of the airplane will be maintained or turns of the airplane carried out at any angle required. It has been admitted above that the axis of the gyroscope does not change its position with regard to the ground. It can not

- 3 -

be otherwise.

In consequence of the basic property of the gyroscope to maintain the position of the axis of its rotation in relation to the immobile space and in consequence of the daily rotation of the earth, the axle of the gyroscope will keep "fictitious" movement, i.e. it will change its position according to the objects around.

Besides - as the result of friction in the axes of the gimbal system of the gyroscope and by durable disbalance, the gyroscope can reach precision movement, which will also compel the axis of the gyroscope to revolve in relation to earth.

Considering that in the directional gyro there is no directive force which would set the directional gyro by the median, the readings of the instrument should be from time to time compared and corrected in accordance with compasses /magnetic compass, radio compass etc./, which should be on board of the airplane. The correction of readings of the instrument will be carried out by the locking mechanism.

Construction.

One of the sensitive elements of the directional gyro GPK-48 is the gyroscope, free to move around three axis which is suspended in gimbal frame. The proper axis of rotation of the gyroscope is to be found in horizontal position /Fig.3/.

The horizontal position of the gyroscope axle is maintained by a special horizontal correction. This correction sets the axle of the gyroscope into a position perpendicular to the axis of rotation of the outer frame of the gimbal system, and the outer frame is vertical when the airplane is in horizontal position.

The sensitive element of the horizontal correction is the collector switch, the executive element is the motor-corrector.

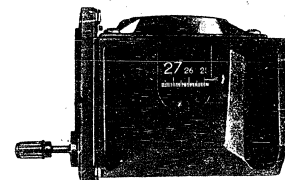


Fig.3. Directional gyro GPK-48 without casing.

Gyrometer

/Fig. 4, 5, 6/

The gyrometer, the outside view of which is shown in figure 4 is an asynchronous electromotor, fed by three A.C., which generates the intensity of 36 V, 400 periods per sec.

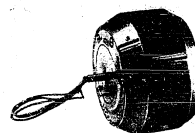


Fig.4. Gyrometer CM-4

Unlike the common electromotors for industrial purposes stator 17 of the gyrometer of the directional gyro GPK-48 is inside the rotor 1 /Fig.5/.

Such a construction enable to gain the maximal inertitudinal moment of the rotor necessary for keeping the stability of the gyro.

When using the asynchronous principle there is no need of collectors and slip rings.

The armature of the stator 12 of the gyrometer is composed of laminae of electric steel marked E4A, which has a small surface of hysteresis, i.e. small losses by remagnetizing.

- 5 -

The stator one-pole winding of the gyromotor is made of copper wire 27 mm insulated by viniflex varnish. The system of the stator winding is shown in Fig.6. By flow of alternative current of 400 periods per sec. through the three phase winding of the stator there arises a rotative magnetic field around the stator. The speed of rotation of this field is equal to 24.000 revolutions per sec. Rotor 1 of the electromotor consists of a brass flywheel /Fig.5/ around which is impressed the iron core of rotor 2. The rotor 2 consists of lamina made of electric steel E4A and of the iron core of the stator.

The short circuit winding of the rotor is made in "squirrel cage" consisting of 19 aluminium pivots 3 connected together by frontal aluminium rings 10.

The "squirrel cage" is produced by casting under pressure the iron core with aluminium alloy.

By crossing the pivot of the stator winding by the rotating magnetic field of the stator, electric current induced in the pivots.

The rotation of the rotor is the result of interaction of current fields, flowing through the winding of the stator and of the rotor. The rotor speed is 21.500 to 23.000 rev. per min.

The rotor of the gyro is joined through flanges 18 and 4 /see Fig.5/ with the inside rings of six bearings. The outside ball retainer ring 5 rest in bearing brushes 9 and 16 which are impressed in the stationary axle 7 of the stator 17.

In the gyro motor of the electric directional gyro GPK-48 there are used radial-axial ball bearings of high class precision of type 6.005 K with textolite ball distance rings 13. The dimension of the bearings is 5 x 16 x 5. The bearings are to be greased by frost-resisting lubricant OKB-122-7. In bearing bushes 9 and 16 there are lubrication washers 6 and 14, which serve as containers for lubricant.

- 6 -

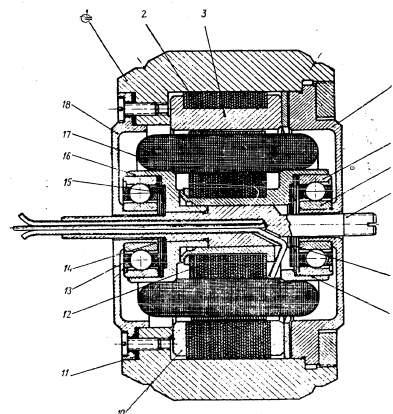


Fig.5. Construction of the gyro.

1 - rotor, 2 - iron core of the rotor, 3 - pivot winding of the rotor, 4 - flange, 5 - outside ball retainer ring, 7 - stator axle, 8 - washer for lubrication, 9 - bearing bush, 10 - ring, 11 - insert of air regulation, 12 - iron core of the stator, 13 - ring ball distance, 14 - washer for lubrication, 15 - spring washer, 16 - bearing bush, 17 - stator, 18 - flange.

When the instrument is in function, spring washer 15 protects the bearing from jamming at low and high temperature, because of differing changes in detail caused by temperature.

Angulation of pressure of the spring washer is done by means of inserts, which are placed under the flange of the rotor. The dynamic balance of the rotor is carried out by boring holes in the front mass of the rotor.

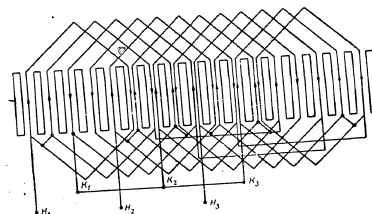


FIG. 6. Scheme of the electric winding of the gyro.

$H_1 H_2 H_3$ - beginnings of the winding correspond with the first, second and third phase
 $K_1 K_2 K_3$ - endings of the winding correspond with the first, second and third phase

Horizontal correction.

The horizontal correction of the directional gyro GPK-48 serves for keeping the axis of the gyro revolutions and the axis of rotation of the outside of the gimbal system perpendicular.

Switch 1 /Fig. 7/ is a sensitive and operating element of horizontal correction and is rigidly joined with the outer frame of the gimbal system. The switch is a collector with two platinum-iridium half rings, under pressure with the armature.

One of the two half-rings of the collector-switcher is connected with one phase A.C. by means of which the instrument is fed. The second half-ring is switched off.

The executive element of horizontal correction is the motor corrector. The motor corrector is represented by two phase multiple reversible asynchronous motor functioning in braked position /see circuit principle/.

The motor - corrector rotor /Fig. 8, 9 and 10/ is packed 3 composed of plates of electric steel marked $\text{E}44$; this steel has little coercive force with rest of induction on left ring 2.

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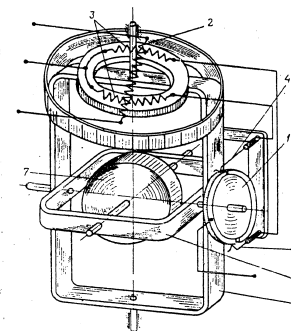


Fig.7. Kinetic scheme of Gimbal system of the gyroscope with a scheme of horizontal correction.

1 - switch, 2 - principal winding of the rotor of the motor corrector, 3 - directional winding of the rotor of the motor corrector, 4 - brushes, 5 - outer frame of the gyroscope gimbal system, 6 - gyroscope.

In grooves the rotor packed there are inlaid its windings 1 /one principal winding and two operating windings/. The principal winding is made of copper wire which is insulated by viniflex insulation PEV. Diameter of the wire is 0,27 mm.

The operating windings are made of copper wire insulated high quality enamelled insulation.

The stator of the corrector /Fig.11 and 12/ is composed of packet of laminations, being a collection of plates made of electric steel /as well as the iron rotor packet/ and of short circuit windings of the "squirrel cage" type which is made of aluminium alloy AL 3 cast under pressure.

- 9 -

The laminations are arranged to create a sloped /slanted/ groove, one tooth behind the other. Such slator construction eliminates possibility of the slator "sticking" to the rotor.

Correction is effected in the following order: When the instrument is locked, i.e., when the gyromotor axis is perpendicular to the rotating axis of the outer frame of the gymbal system, both branches 4, joined with operating winding 3 of the corrector rotor /see the scheme of horizontal correction in fig.7/ which are located on the switcher halfting which is connected with phase of tension.

At the same time the current flows through both operating windings, their circuits being closed. The operating windings are switched into the electric circuit of the instrument in the way that currents which flow through those winding create by interaction with current flowing through the principal winding rotating fields directed to various sides. The corrector total moment is therefore practically equal to zero.

At gyroscope axis divergence from perpendicular position by 2° to 40° to one or another side, one of the brushes passes from the ring fed by current to the switched off halfting. At the same time the circuit of one of the windings is broken. Because of displacement in space and owing to the phase /chronologically/ between currents of the principal and the secondary winding which is left switched on, the operating winding makes up a rotating magnetic field which by its rotation crosses the short-circuited windings /"squirrel cage" pivot/ of the stator and includes currents in them.

- 10 -

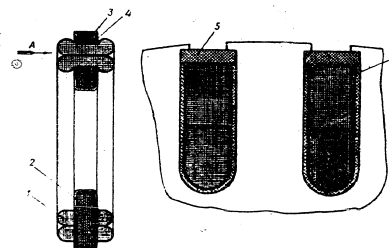


Fig. 8. Construction of motor of the corrector motor.
1 - winding, 2 - ring, 3 - packet of laminations, 4 - front lamination, 5 - wedge, 6 - groove insulation.

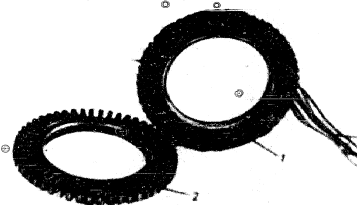


Fig. 9. Rotor of corrector motor.
1 - rotor with windings
2 - packet of laminations in a ring

- 11 -

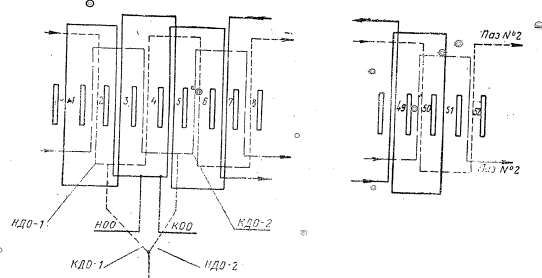


Fig. 10. Scheme of rotor winding of the motor corrector.

N00 - Beginning of principal winding
 K00 - End of principal winding
 K00-1 - Beginning of the first operating winding
 K00-1 - End of the first operating winding
 N00-2 - Beginning of the second operating winding
 K00-2 - End of the second operating winding

Because of interaction of the magnetic field and field of currents in the slator pivots, there is created between the slator and the rotor a force which tends to turn the rotor in relation to the slator.

The direction of this force can be defined by means of the physical "rule of the left hand".

As a result of this force a momentum is created in relation to the outer axis of the gimbal system of the gyroscope.

- 12 -

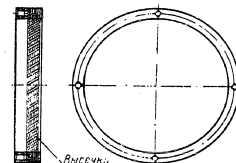


Fig. 11. Stator of horizontal corrector.

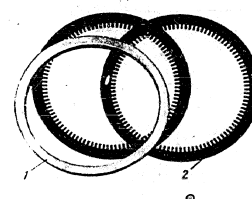


Fig. 12. Construction of the horizontal corrector stator.

1 - stator, 2 - lamination

By effect of this momentum the byroscope presses in a direction where disturbance of the perpendicular alignment of the axes is created.

A declination of the gyromotor axis from its perpendicular moment to another direction, the second operating winding of the stator corrector rotor is switched off, direction of the momentum changes and the gyroscope presses to reverse direction i.e. again in the

- 13 -

direction of the restored perpendicular alignment of the axes.

Arresting mechanism

/Fig.13 and 14/

Arresting the instrument and getting the card of the instrument in the given course is done by means of the arresting knob 1/ Fig.13/ attached to the shaft 2, which must be pushed into its final position. Disc 3 which has twenty apertures round its circle is attached to the shaft 2 and is coupled with disc 4, equipped with two impressed clutching pegs. Together with movement of shaft 2, cylinder 5 is also moved.

At movement of the slider, protuberance 7 of the arresting fork 9 slips along the slope of the slider 6. The arresting fork turns about its axle 10 and by means of attached guides which fall into the cog wheel groove of the arresting muff 12, lifts the muff. At moment of the arresting cog wheel muff 12 upwards, the pins 13 impressed in the muff fall into apertures of the disc with stands 33 /see Fig.14/.

By means of this arrangement the outer frame of the gimbal system is stopped and the gyroscope loses of its free movements around three axes. At the next movement of the arresting muff upwards, it leans its upper part against the disc with stands 33 /see Fig.14/.

By means of this arrangement the outer frame of the gimbal system is stopped and the gyroscope loses one of its free movements around three axes. At the next movement of the arresting muff upwards, it leans its upper part against the disc with stands 33 and begins to lift it. The arresting frame 32 which is pressed by spring 36 to the disc with stands, starts to revolve simultaneously about axle 37. The arresting frame 32, when revolving, passes by its teeth 31 the cam 30 which is attached to the casing of the gyromotor 8.

- 14 -

In addition the gyromotor starts to rotate, and when the axle of the gyroscope is perpendicular to the axle of the revolving outer frame of the gimbal system, tooth 31 of the arresting frame 32 falls into the groove of cam 30. The gyrogroup is thus prevented from turning by the other frame. In this way the inner frame of the gimbal system /gyrogroup/ is stopped and the gyroscope loses two of its free movements around three axes.

The turn of the card of the directional gyro to the required angle is carried out as follows:

By turning the arresting knob 1 /see Fig.13/ the movement of it is transferred to the outer frame of the gimbal system where the card is attached. The transmission of movement is carried out by means of the worm 5, which is joined with the arresting shaft 2 by engagement of the disc 3 and 4, then by means of the worm wheel 14 and by means of the cylindric wheel, co-axially attached to the worm wheel 14 and by means of the arresting cog wheel muff 12 attached to the disc with stands, which disc is engaged with this muff by pins 13 and is attached itself to the outer frame.

By turning the frame, the card which is attached to it can be fixed to the course required.

The gyroscope is set free by pulling the arresting knob 1 straight until its final position. In addition, the disc with apertures 3 disengages the disc with clutching pegs 4. The slider 6 moves together with the arresting knob 1. In addition protrusion 7 of the arresting fork appears above groove of the latch 17 and by effect of the spring 11 sinks down together with the fork and draws the arresting cog wheel muff 12. The cog wheel muff is disengaged from the disc with stands. By effect of the spring the arresting frame sinks down, its tooth comes out of the cam groove and the gyrogroup is set free.

- 15 -

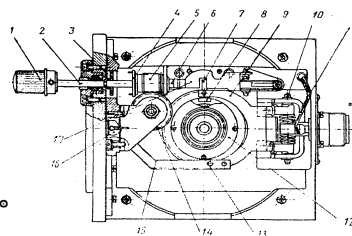


Fig.13. Body with arresting mechanism.

1 - arresting knob, 2 - shaft, 3 - disc with apertures, 4 - disc with clutching pegs, 5 - worm, 6 - slider, 7 - tang, 8 - guide quill, 9 - arresting fork, 10 - axle of arresting fork, 11 - spring, 12 - cog wheel muff, 13 - pin, 14 - worm wheel, 15 - spring, 16 - signal flag, 17 - latch.

For the purpose of determining whether the instrument is arrested or free, there is provided the signal flag 16, one part of which is painted red, the other black.

At arresting the instrument, the signal flag is kinetically connected with the arresting fork 9 and by means of the spring 15 is lifted upwards.

On the front part of the instrument in a little window of the screen, a red flag will appear. At disarresting the signal flag sinks down and covers the little window in the screen with its black painted part.

- 16 -

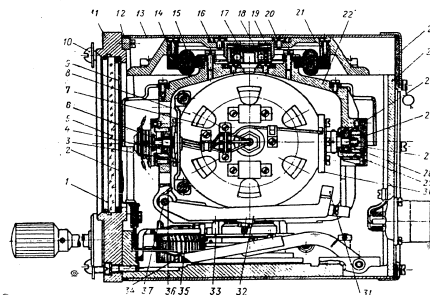


Fig.14. Entire view of the directional gyro GPK-48
/oblong cut/

- | | |
|----------------------------------|---------------------------------|
| 1 - snap ring | 20 - screw |
| 2 - signal flag | 21 - lid of the body |
| 3 - bush | 22 - frame |
| 4 - ball bearing | 23 - washer |
| 5 - glass | 24 - cover |
| 6 - axle | 25 - ball bearing |
| 7 - gyrometer | 26 - axle |
| 8 - gyrometer casing | 27 - safety nut |
| 9 - screw | 28 - nut |
| 10 - screw | 29 - protecting case |
| 11 - front flange | 30 - arresting cam |
| 12 - washer | 31 - tooth of the arresting cam |
| 13 - casing | 32 - arresting frame |
| 14 - horizontal corrector slator | 33 - disc with studs |
| 15 - horizontal corrector rotor | 34 - cylindrical cog wheel |
| 16 - flange | 35 - worm wheel |
| 17 - regulative washers | 36 - spring |
| 18 - spring plate | 37 - axle |
| 19 - bush | |

- 17 -

Overall view of the instrument./Fig. 14 and 15/

The inner frame of the gimbal system of the gyroscope 18 represented by the gyrogroup, composed of the gyromotor 7 in gyro-motor casing 8.

The gyrogroup can turn by $\pm 60^\circ$ about the horizontal axis in relation to the outer frame 22 of the group of the gimbal system. The frame 22 revolves angularly about the vertical axis without limit in relation cover 24 of the instrument. To the gyromotor casing 8 there are screwed two axes 6 and 26 on which there are put the inner ball bearing rings of the gyrogroup.

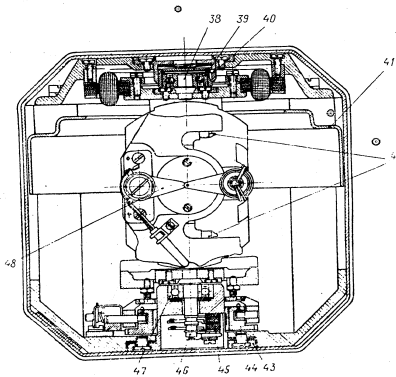


Fig.15. Overall view of the directional gyro GPK-43 /crosscut/.

- | | |
|---------------------|--------------------------------|
| 38 - axis, | 44 - screw |
| 39 - ball bearing | 45 - group of leading contacts |
| 40 - peg | 46 - axle with contact rings |
| 41 - card | 47 - ball bearings |
| 42 - balance screws | 48 - group of central contacts |
| 43 - bottom flange | |

- 18 -

The radial ball bearings 4 and 25 of the gyrogroup marked No. 23A with metal ball retainer ring of dimension $3 \times 10 \times 4$ have a high degree of precision /class 4/.

The moment of friction of these ball bearings does not exceed 0,4 g/cm. The inner ring of the ball bearing 19 is rigidly attached to the axle of the gyrogroup 26 by means of a nut 28 and by the safety nut 27. Its outer ring is rigidly joined by a flange with the outer frame of the gimbal system of the gyroscope.

The inner ring of the bearing 4 is rigidly attached to the axle of the gyrogroup in such a way, that both the inner and the outer ring of the bearing 25 is enabled to turn in axial direction inside the bronze bush 3 which is attached to the outer frame of the gimbal system. Such a construction enables to compensate the varying temperature differences of the gyrogroup elements and of the outer frame of the gimbal system and enables the bearings to get in position in order to obtain the minimal moment of friction. The gimbal system group leans by its bottom axle against the radial-axial ball bearing with the outer take-off rings marked 600 5 K-1.

The mentioned bearing has a brass ball retainer ring of dimension $\emptyset 5 \times \emptyset 16 \times 5$.

The outer ring of the ball bearing sits in the flange 43, which is attached by screws 44 to the bottom of the instrument body.

The upper axle 38 of the gimbal system group revolves in bearing 39, which is of the same type as the bearing of the lower axle. The outer ring of this bearing sits rigidly in the steel bush 19 which is able to move in axial direction inside the bronze flange 16 attached by screws on the lid 21 of the instrument body. In order to enable the bush to revolve in the flange 16, a group is milled in the bush into which falls peg 40 which is impressed into the flange 16.

The selection of axial freedom of the group of the gimbal system is carried out by the spring-plate 18. The pressure of this spring

- 19 -

plate is regulated by washers 17. At working position when axial freedom of the group of the gimbal system is limited from 0,04 to 0,06 mm, pressure of the spring plate does 500 - 800 g.

On the upper part of the outer frame of the gimbal system is attached the card of the instrument 41. The card is marked. Value of every point is 1°. Every 10° point is figured. To the same frame is attached the horizontal corrector rotor 15.

The horizontal corrector 14 is attached to the lid 21 of the instrument box.

In the lower part of the instrument there is mounted the arresting mechanism and the loading system. To the front part of the instrument body is attached by screws the flange 11. On the flange are attached the non-reversible nuts, provided with screws 10, holding down the instrument to the panel. In the flange is a circular window into which is placed a screen 9 with opening for card and with an index by means of which is done the reading of instrument indications. The window is covered with glass 5 and is kept by the snap ring 1.

To the back wall of the instrument body there is attached the three-point electric plug /bullet connection/.

The entire instrument is protected by an aluminium casing 13 which is held by screws to the back wall of the instrument body. To safeguard the instrument before dust and moisture, rubber washers 22 and 23 are put under the casing.

Electric system. /Fig.15, 16, 17/

The feeding is conducted by movable parts to the separate instrument elements according to the instrument electric scheme /Fig. 16/.

- 20 -

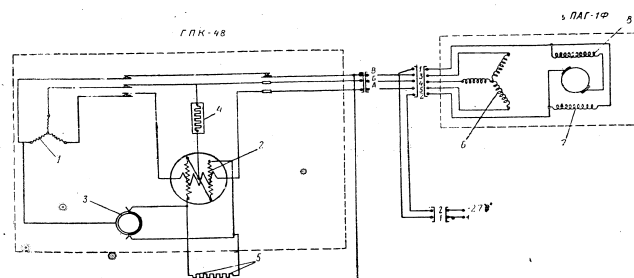


Fig. 16. Electric scheme of the GPK-48.

- 1 - three phase gyromotor winding
- 2 - motor corrector winding
- 3 - rotary converter of the correction
- 4 - ballast resistance
- 5 - spark resistance
- 6 - rotary converter generator winding
- 7 - shunt motor winding of the rotary converter
- 8 - motor rotary converter winding in series

To the outer frame of the gimbal system of the gyroscope which is attached by the lower flange 43, the feeding is conducted by immovable group of loading contacts 45 (see Fig. 15). This group of contacts consists of contact springs which are produced as the bronze spring plates which are soldered together with the cold hardened silver plates.

The plates are insulated from the other, as well as from the instrument body by means of washers and sleeves, made of electro-insulating material.

The movable group of loading 45 is mounted in the lower part of the gimbal system. It consists of two contact rings and of the central contact, the end of which is provided with an edge.

- 21 -

The contact rings and the lid are put on the axle by textolite sleeve and washers which insulate these rings and the lid from each other and from the axle.

The axle with contact rings is shown in Fig.17.

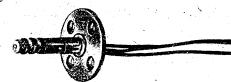


Fig.17. Axle with contact rings.

Thus, the three phase alternating current which feeds the instrument is connected with the outer frame of the gimbal system by a central contact and by two contact rings.

The gyrogroup is fed by means of the conductors 48 with little momentum of force /Fig.15/ carried out as central point contacts.

The immovable group of leading conducting contacts is mounted to the outer frame of the gimbal system and the movable group of leading conducting contacts is mounted on a special bracket which is attached to the gyrogroup. The contacts take place at points on the axis of the gyromotor rotation.

Such a construction enables the feeding of the gyrogroup on it a very little momentum of friction.

Principal characteristics of the instrument:

- | | |
|-------------------------|---|
| 1. Feeding | three phase alternating current of 36 V intensity and of 400 Hz frequency |
| 2. Current power needed | maximal 0,32 A |

- 22 -

3. Momentum of inertia of gyroscope rotor 1,8 g cm/sec²
4. Speed of the gyroscope motor rotation 21.500 - 23.000 turns/min.
5. Kinetic momentum of the gyroscope 4.000 gcm/sec
6. Stability of indications maximal drift $\pm 3^\circ$ within 15 min.
7. Caloric extent of work from 50° to 60°
8. Precession speed from the horizontal correction 3 - 6 min.
9. Weight of the instrument 2500 g
10. Entire dimensions 117 x 115 x 129

Mounting of directional gyro GPK-48 in aircraft

The rotary corrector together with the directional gyro and the board circuit must be connected according to the the following scheme:

No of the pin in the electric plug PAG-1F	Location of connection of pins in electric plug GPK-48	connection of board circuit terminal
1	B A	+
2		-
3		
4		
5		

Not keeping this order of connections causes irregular function of the instrument.

Control of the directional gyro GPK-48.

The directional gyro is controlled by the tester UFG-48 /Fig. 7. The instrument is mounted on a special bracket which is held down to the testing block.

The accurate function of the directional gyro is tested as

- 25 -

1. Exact function of the arresting device
2. Time needed for a certain number of gyromotor revolutions
3. Current used
4. Stability of instrument indications at its swinging on the tester UPG-443.

The control of the instrument is carried out in the following order:

Feeding of the rotary converter is switched on by the switch 11 /Fig.24/. By means of the rheostat 4, according to the Voltmeter 12, set the intensity of 27 V. At the same time the rotary converter must generate the intensity of 36 ± 1 V at 400 ± 10 Hz frequency. This is controlled by the Voltmeter 5 and by the frequency meter 6. The starting time of the gyromotor is determined by the ammeter according to time of the decrease of current, needed by the instrument.

The starting time of the gyromotor must not exceed 5 min., and the steady current must not exceed 0,32 A.

To control the current force of all the three phases, there must be provided a threepole rotary converter for three positions /or another device which would enable to measure the current at all phases/.

The function of the arresting device is controlled. The arresting device must function fluently, without any jamming. When the gyroscope is arrested, there must appear on the front side of the instrument in the window of the screen a signal of red colour; at free position of the instrument, this signal disappears. Simultaneous appearance of the red and black colour in the window of the screen is not permitted.

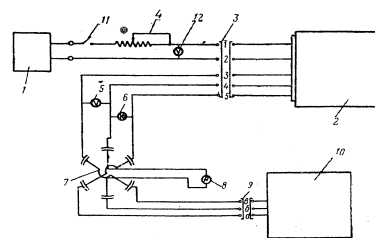


Fig.17. Principal electric scheme of the tester GPK-46

- 1 - source of continuous current of intensity 2 V
- 2 - rotary converter P43-1F
- 3 - electric plug
- 4 - regulating rheostat
- 5 - voltmeter of alternating current
- 6 - frequency meter
- 7 - three phase-position rotary converter
- 8 - ammeter of the alternating current
- 9 - electric plug
- 10 - directional gyro GPK-46
- 11 - switch
- 12 - voltmeter

The stability of indications of the directional gyro is controlled. The instrument is attached to the bracket of the device UPG-46 and the current is switched on.

Within 5 minutes when the gyroscope motor reaches the normal speed the card of the instrument is set to the zero degree heading by means of the arresting device; then is the instrument disarrested. At the same time the testing block UPG-46 must be in the horizontal position.

Then by means of a special lever the testing block stoppes by 7,5° and sets in the swinging of the testing block. 15 minutes after setting off the testing block, the block returns back to its horizontal position and the movement of the card is to be recorded.

- 25 -

Then repeat the control of headings 90° , 180° and 270° .

The stability of the readings /indications/ is characterized by the drift of the card.

The drift of the card of each of the four cardinal headings 0° , 90° , 180° and 270° must not exceed $\pm 3^{\circ}$ in 15 minutes/.

A maximum of $\pm 5^{\circ}$ drift is permitted on any one heading when the total drift of the four headings does not exceed 12° .

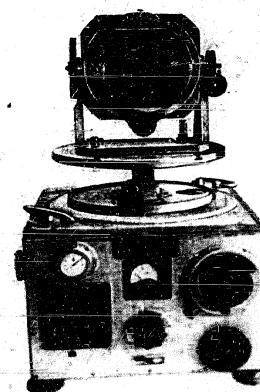


Fig.18. Directional gyro GFI-45 on the tester for gyroinstruments UPO-45.

Disassembly of GFI-45 and their removal.

Within a long working process of the instrument there may appear drifts of the card to one side exceeding the permits stipulated by the technical regulations for the instrument. It is caused

- 26 -

by the disturbed balance of the gyrogroup. To remove such an error it is necessary to balance the gyrogroup perfectly.

To do this, it is required:

- 1/ To unscrew eight screws on the back wall of the instrument.
- 2/ To remove the casing
- 3/ To turn the screw by a screw driven through the window in the side wall of the instrument /see Fig.15, detail 42/.

If the card of the instrument drifts aside to higher values, the balance screw should be turned counterclockwise.

If the card of the instrument drifts aside to little values, the balance screw should be turned clockwise.

The reparation of the instrument should be done in a clean place because any dust and dirt may bring the instrument out of function. Other errors of the instrument, such as jamming of the arresting mechanism drifts to various sides to various headings which exceed the TR permits, bringing the gyromotor out of function and it can not be repaired under the airfield conditions.

The instrument which show such errors should be delivered for a repair to the producer.

How to use the instrument:

For using the instrument at flight the following is needed:

1. Switch on the current of the rotary converter
2. After 5 minutes, as soon as the gyromotor reaches sufficient speed, the card must be set to the necessary heading according to the magnetic compass or according to any other navigation device being at the disposal of the crew of the airplane. If the arresting knob of the arresting mechanism is pushed down to its end position by smooth turning of the arresting knob, the corresponding point of the card compensates with the indicator line of the instrument. /Fluorescent index pointed on the screen of the frontal part of

- 27 -

the instrument/. When the instrument is to be disarrested by pulling the knob out to its end position. At disarresting, the knob should not be turned, as it could cause false readings of the instrument.

The card being set to the given course, the arresting knob must be turned smoothly and slowly, in order to prevent the axes of the gyrogroup from great efforts, which could cause damage of ball bearings and disbalance of the gyrogroup.

After setting the card of the instrument to the given course, the instrument may serve as a constant course indicator at intervals of 15 - 20 minutes.

The readings of the directional gyro must be compared periodically every 12-20 minutes with the readings of any other compass.

At making acrobatic turns and at steep bank turns exceeding 60° as well as at taking-off and landings, the directional gyro must be disarrested.

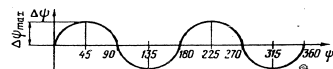
Before the instrument is required for service, the following should be considered:

1. Before rolling out for start it is necessary to feed the instrument with electric current and to disarrest the instrument for 2-3 minutes, then at taking-offs at flight and at landings it is not necessary to arrest the instrument.

2. When the airplane is turning, the directional gyro does not indicate at given moments the actual angles of turning, which is caused by its proper construction, a so called "cardan's error". This is the reading error. It arises at the bank of the airplane and disappears at its level position.

The law of changing the "cardan's error" in a turn has a shape as presented in the following figure:

./.



The "cardan's error" is equal to zero at the course = 90°, 180°, 270°, 360° and reaches maximum at the courses 45°, 135°, 225°, 315°. The "cardan's error" is the greater the steeper is the bank of the airplane.

The dependence of the maximal value of the "cardan's error" on the bank angle of the airplane is expressed in the following table:

	0	15°	30°	45°	60°
4 max	0	1°	4°07'	9°42'	19°28'

As the result of the "cardan's error" appearance the instrument indicates an irregular rotational speed at a time when the airplane is turning evenly, in fact.

This fact should be considered when using the instrument.

For the use of the directional gyro for carrying out turns, it is necessary to set the instrument to zero and the rotational angles read up from the zero. Such use of the instrument is favorable because the "cardan's error" does not appear at turns in angles 90, 180, 270 and 360°, the result of which enables to operate the airplane from the turn to the wanted direction more precisely without any additional corrections.

Thus, while using the GPX-46 for flights above the airfield the instrument must be set to zero before taking off in course of the starting and landing path.

For a flight "on a circle" no corrections of the GPX-46 should

- 29 -

be done when comparing its indications with the compass.

While landing under bad meteorological conditions and at night after returning to the airfield, it is necessary to set the directional gyro to zero according to the landing course by orders of the navigator. It is possible to use the instrument for reading out the landing.

The recommended direction for using the directional gyro for flight does not exclude the possibility to use the instrument by a recommended method in the technical description of the instrument, i.e. the card of the GPK-46 is set according to a magnetic compass or to any other compass.

It must be always considered, however, that the GPK-46 cannot keep its course unchanged in azimuth, consequently, within same time, its indications differ in the given course in comparison with a magnetic compass. In a normally functioning instrument the drift speed does not exceed 5° in 15 min.

It is possible to compare the indications of the GPK-46 with those of a magnetic compass DMEK-3 only in a straight flight.

After a take off or after a turn by any angle before the card of the GPK-46 is set up according to any compass, it must be waited until the compass card /compass indicator/ becomes still.

If the card of the GPK-46 is set up according to any compass and then soon afterwards a turn is done in whatever angle, it is then possible to compare the indications of these instruments after a turn, assuming a changed deviation of the compass in a new course and under the condition that the needed time was kept up, as it was said above.

DIRECTIONAL CYRO

Model IIR-52

(Navigational aid)

DESCRIPTION AND OPERATION INSTRUCTIONS

I. PURPOSE AND PRINCIPLE OF OPERATION

Earlier produced directional gyros models IHK-46, IHK-48 and others are flight instruments used to perform precise aircraft turns through a preset angle, to fly rectangular landing traffic pattern and to maintain a certain flight direction for a short period of time.

Due to its high degree of precision the IHK-52 directional gyro is used as a navigational instrument in addition to the above described flight functions performed the other directional gyros.

The IHK-52 permits flying the great circle (i.e. flying over the shortest distance between two points on the Earth surface) for an extended period of time (1-2 hours).

In addition to being a visual display instrument the IHK-52 directional gyro is a transmitter of electrical signals depending on flight direction. These signals may be used for the IHK-49 indicators, duplicating the IHK-52 directional gyro indications, as well as for the HM-50 ground position indicator, autopilots and other instruments.

The IHK-52 directional gyro is designed for flying at any latitude of the northern hemisphere and in the North Pole area where neither magnetic nor geomagnetic compasses can be used.

The IHK-52 directional gyro principle of operation is that of a gyroscope with three degrees of freedom, which maintains the constant position of its axis of rotation in space.

The gyroscope rotor axis is held in the horizontal plane by means of the horizontal erection mechanism. A liquid level switch (rheostat) serves as a sensing element of the horizontal erection mechanism.

As distinct from other directional gyro systems for azimuth erection the HMK-32 directional gyro is provided with an azimuth erection mechanism, designed to correct an instrument error caused by the vertical component of the vector of the earth's twenty-four-hours' rotation angular velocity and to compensate the gyro unit unbalance.

Deviation of the aircraft centre line from the established heading is determined by mutual position of the dial on the gyro gimbal ring, vertical axle and the index on the instrument casing.

A free gyro whose centre of gravity coincides with the point of intersection of all the three axes is "static" relative to the stars and has a visible "drift" relative to the rotating earth.

At the North Pole a free gyro with the horizontal axis of rotation "drifts" at an angular velocity equal to that of the earth's rotation ($U=15 \text{ deg/hr}$).

At any other latitude of the Northern hemisphere the angular velocity of the gyro visible drift is equal to the vertical component of the earth's rotation angular velocity vector at the given latitude.

$$\omega = U \sin \varphi \quad (1)$$

where ω - angular velocity of the gyro visible drift.

φ - latitude.

To compensate the gyro visible drift it is necessary to impose a moment on its horizontal axis

$$M_{\varphi} = H\omega = H U \sin \varphi \quad (2)$$

where H - gyro kinetic moment.

- 2 -

At the latitude of the place where the unit was manufactured the directional gyro is balanced so as to preclude any visible drift of the gyro, i.e. by unbalancing the gyro impose a moment on it

$$M_{q_0} = H_u \sin \varphi_0 \quad (3)$$

φ_0 - latitude of the place where the unit was manufactured.

To prevent the gyro from drifting at any other latitude a moment should be applied to it

$$M_{\varphi} = M_{q_0} + M_{el} \quad (4)$$

where M_{el} - the torque developed by the azimuth erection torque motor.

From the expression (4)

$$M_{el} = M_{\varphi} - M_{q_0} \quad (5)$$

and substituting the values of the M_{φ} and M_{q_0} from the formulas (2) and (3), respectively in the formula (5), we obtain

$$M_{el} = H_u \sin \varphi - H_u \sin \varphi_0 = H_u (\sin \varphi - \sin \varphi_0)$$

The torque developed by the azimuth erection torque motor is produced in the directional gyro transmitter by supplying voltage to the azimuth erection torque motor control winding, the voltage varying with place latitude according to the relationship determined by the expression (6).

Without opening the unit the azimuth erection mechanism is used to compensate the gyro assembly imbalance which may appear in the course of continuous operation of the unit.

The voltage required to obtain the compensating moment is supplied to the azimuth direction torque motor control winding from the special correction potentiometer installed in the control unit.

The course signal is received by the HMA-49 indicators through the potentiometer transmission from the three-tape potentiometer supplied with 120 volt current through two pairs of wipers located on the unit.

The azimuth direction dial is set for a required direction by the azimuth control knob located on the control panel.

When the azimuth control knob is turned through a large or small angle, and on the other side, the directional gyro dial rotates proportionally with higher or lower speed. The dial is rotated also by the HMA-49, 50 potentiometer control winding, which is connected to the azimuth control knob and the azimuth output potentiometer, a three-dial line, and the dial, to the potentiometer relative to the azimuth dial ring.

This system ensures setting of a required heading, without requiring a moment on the gyro which is the case in the systems with a constant rate.

To reduce after-turn errors, provision is made in the HMA-49 directional gyro for automatic cutting out the horizontal erection mechanism when the aircraft makes turns at an angular velocity of 1 deg. per sec. or higher. The horizontal erection mechanism is cut out when the horizontal erection torque motor control windings are energized by a gyroscopic erection cut-out switch.

II. COMPLETING

The IIR-52 directional gyro set (Fig.1) comprises the following units:

- | | | |
|--------------|--------------------------------|---|
| 1. IIR-52 | directional gyro (transmitter) | 1 |
| 2. IIR-52-IV | control panel | 1 |
| 3. BM-5APE | erecting cut-out switch | 1 |
| 4. HT-70 | inverter | 1 |
| 5. IIR-49 | indicator | 2 |
| 6. IIR-52-CN | junction box | 1 |



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Fig.1. IIR-52 Directional Gyro Set

- 1 - HT-70 inverter; 2 - IIR-52-IV control panel;
3 - IIR-52-CN junction box; 4 - IIR-52 directional gyro;
5 - IIR-49 indicator; 6 - erecting cut-out switch.

III. ITHK-52 DIRECTIONAL GYRO ELECTRICAL SYSTEM

The ITHK-52 directional gyro set is supplied with 36 V, alternating current of 400 c.p.s. frequency stabilized to within $\pm 2\%$ and with $27 \text{ V} \pm 10\%$ direct current. The HT-70 inverter which converts the aircraft electrical system direct current into alternating current is usually used as an alternating current source.

Direct current is supplied to the set directly from the aircraft electrical system.

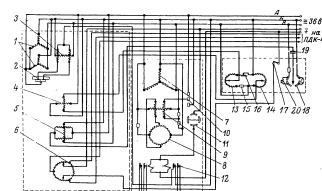


Fig. 2. ITHK-52 Directional Gyro Wiring Schematic Diagram

1 - Gyro motor stator windings; 2 - liquid level switch; 3 - horizontal erection torque motor windings; 4 - azimuth correction torque windings; 5 - AMM-0,5 electric motor; 6 - transmitting potentiometer; 7 - BK-53PE gyro motor windings; 8 - potentiometer; 9 - AMM-0,5 electric motor; 10 - contact segments; 11 - contact disk; 12 - relay; 13 - latitude potentiometer; 14 - correction potentiometer; 15 - resistor; 16 - adjusting resistor; 17 - power switch; 18 - dial turn transmitter segments; 19 - capacitor; 20 - adjusting resistor.

Basic consumers of the A.C. power are the stators windings (1, Fig.2) of the two three-phase asynchronous electric motors rotating the gyro motor rotor. The windings of these motors are "star" connected and connected to the A.C. circuit parallel to each other.

The liquid level switch is a sensing element of the horizontal erection mechanism. It controls the currents flowing through the control windings (3) of the horizontal erection torque motor rotor which is an actuating element of the horizontal erection mechanism holding the gyro axis in the horizontal plane.

The horizontal erection torque motor is a two-phase reversible asynchronous electric motor running at braked rating.

Its main winding is constantly connected to the set electrical circuit, and the control windings are connected to the circuit through the liquid level switch (2).

The azimuth erection mechanism, as well as the horizontal erection mechanism, is a multiphase asynchronous electric motor but as distinct from the horizontal erection torque motor (which has two control windings) the torque of this motor is reversed by changing the phase of the voltage supplied to its control winding.

The azimuth erection torque motor has two windings: the main winding is constantly connected to the set electrical circuit (between the phases A and B, see Fig.2). The other control winding is supplied with voltage from the diagonal line of the resistance bridge, formed by the two potentiometers (13 and 14) and resistors (15) located in the control panel.

When the wipers of the latitude potentiometer (13) and correction potentiometer (14) are moved relative to the middle position of the electrical resistance bridge, current begins flowing through the azimuth erection torque motor control winding connected in the diagonal line of the bridge.

The torque created by the azimuth erection torque motor makes the gyroscope precess in azimuth.

Heading signals are remotely transmitted by means of the three-taps potentiometer (6). Voltage is supplied to the potentiometer through two pairs of current carrying wipers located 180° apart.

The potentiometer is supplied with 27 V direct current.

The instrument is set for a required reading by turning the dial by means of the AMU-0,5 two-phase induction electric motor (9). The electric motor control is effected from the control panel. The system is provided with step control of dial rotation speed:

1. High speed (above 180 deg./sec.) is ensured by full voltage supplied to the AMU-0,5 electric motor control windings.
2. Low speed (from 25 to 100 deg/sec) is obtained when the AMU-0,5 electric motor control windings are switched on through resistors.

To obtain a required phase shift and ensure equal speeds of the dial at clockwise and counterclockwise rotation the 1 mf capacitor (19) is cut in the circuit of the motor control windings connected in parallel.

The adjusting resistor (20) is provided in the control panel to adjust the speed of the dial rotation. The adjusting resistor (16) is provided in the control panel to adjust the latitude potentiometer efficiency, i.e. to adjust the gyro drift depending on position of this potentiometer wiper.

When the aircraft turns the horizontal erection torque motor is switched off by breaking the circuit of the horizontal erection torque motor control windings through opening the contacts of the relay (17) in the erecting cut-out switch.

The erecting cut-out switch system is outlined in detail in the description of the erecting cut-out switch.

For the ITH-52 system the horizontal erection is cut out at a rate of turning exceeding 0.3 deg./sec.

IV. ITH-52 DIRECTIONAL GYRO SET DESCRIPTION

1. DIRECTIONAL GYRO

As distinct from conventional directional gyros, the directional gyro (transmitter) shown in Fig.3, has the following design features and modifications that ensure high accuracy of indications:

1. The ball bearings are installed on the rotor shaft with no play, the rotor and its housing (gyro motor cover) are made from the same material (steel), the gyro assembly is fitted with a bimetallic plate with weights ensuring stable position of the gyro assembly centre of gravity when an ambient temperature changes from +50°C to -60°C.



Fig.3. Directional Gyro General View

2. The caging mechanism of conventional directional gyros is replaced by a mechanism that allows the instrument dial to be turned through a required angle relative to the gyro gimbal ring without imposing a moment on the gyro.

3. The directional gyro is provided with an azimuth erection mechanism that enables the gyro assembly to be electrically balanced to compensate the gyro visible drift caused by the earth's rotation and possible unbalance due to shifting of the gyro assembly centre of gravity.

4. The provision is made to cut out the horizontal erection in a turn, thus decreasing after-turn errors, which are accumulated by conventional directional gyros during a turn as a result of horizontal or interfering correction effect.

5. The instrument is enclosed in a round housing which prevents unstable drift of the gyro on different rhumbs due to influence of air streams from the ports of the gyro motor housing.

The kinematic diagram of the directional gyro (transmitter) is shown in Fig. 4. The gyro assembly (5) with the liquid level switch (2) is supported by ball bearings in the gimbal ring (4) and may turn through $45-50^\circ$ to either side from the middle position relative to the gimbal ring. The angle of turn of the gyro assembly in the gimbal ring is restricted by the stop (15) butting against the recess in the rod (9).

The angle of turn of the gimbal ring (4) in the casing is unlimited.

The gimbal ring carries:

- a) azimuth erection torque motor stator (6), whose rotor (7) is linked with the gyro assembly pivot;
- b) horizontal erection torque motor rotor (10);

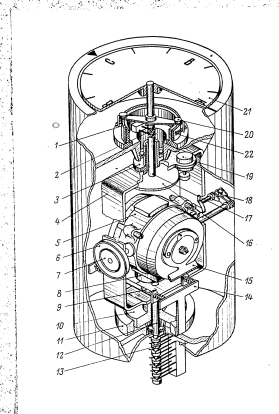


Fig. 4. Directional Gyro Kinematic Diagram.

1 - output potentiometer; 2 - two slip rings assembly; 3 - gimbal ring upper pivot; 4 - gimbal ring; 5 - gyro assembly; 6 - azimuth erection torque motor stator; 7 - azimuth erection torque motor rotor; 8 - liquid level switch; 9 - rod; 10 - horizontal erection torque motor rotor; 11 - horizontal erection torque motor stator; 12 - gimbal ring lower pivot; 13 - seven slip rings assembly; 14 - gimbal ring damper; 15 - stop; 16 - gear; 17 - gear shaft; 18 - point contacts; 19 - DPA-0.5 electric motor; 20 - wiper holder; 21 - dial; 22 - potentiometer wipers.

- c) gimbal ring damper (14);
- d) MHA-0,5 electric motor (19);
- e) gimbal ring upper pivot (3) and lower pivot (12).

The shaft (17) with the gear (16) passes inside the upper pivot (3). Attached to the shaft (17) are: the dial (24), wipers (22) of the output potentiometer (4) and slip rings assembly (2) through which direct current is supplied to the wipers (22),

Alternating current is supplied to the moving parts through the seven slip rings assembly (13).

Power is supplied to the gyro assembly through the group of the point contacts (18).

The directional gyro (transmitter) comprises the following structural elements:

1. Gyro assembly.
2. Liquid level switch.
3. MHA-0,5 electric motor with reduction gear.
4. Horizontal erection torque motor.
5. Azimuth erection torque motor.
6. Output potentiometer.
7. Gimbal ring assembly in casing.
8. Shock mount assembly.

Gyro Assembly

The general view of the gyro assembly is shown in Fig. 1. The assembly is a gyro motor attached to which are the liquid level switch (1, Fig. 6), pivots (3 and 4) securing the gyro assembly in the gimbal ring, balancing units and others.

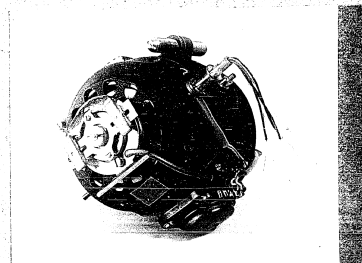


Fig. 5. Gyro Assembly General View

The gyro motor rotor (5) is a steel fly wheel positioned symmetrically with respect to the plane passing through the axis of the gyroscope inner gimbal ring.

The rotor is driven by two asynchronous electric motors with short-circuited squirrel cage rotor windings.

Unlike production conventional asynchronous motors, the gyro motor stator is inside the rotor, thus enabling the rotating parts of the given size to obtain the maximum inertia moment.

The gyro motor casing consists of the aluminum tips (6) and steel covers (7 and 8).

The rotor rotates on the two radial ball bearings (9) with sintered metal cages. The 16026W ball bearings of 60 mm diameter are made to a high degree of accuracy.

The inner races of the rotor bearings are fixed to the rotor trunnions, the outer races of the ball bearings are fitted in the caps (10).

- 2.14 -

The rotor end play is adjusted within the range of 0.1 to 1.15 mm. by placing gaskets (11) under the flanges of the caps (10). Finally the rotor play is removed by tightening the nuts (12). In this case the clamp (2) compresses the springs (13) located between the slide blocks (14). The compression force deforms the covers (7 and 8), which move the outer races of the ball bearings (9) relative to the inner races, and thus the rotor play is removed.

The nuts are tightened until the friction force that must be overridden to turn the rotor reaches 4-6 gr.-cm.

Used for lubrication of the rotor ball bearings is a 122-12 low-temperature grease that ensures normal operation of the gyro motor within the temperature range from -60° to $+50^{\circ}\text{C}$.

The gyro motor stator (15) are screwed to the covers (7 and 8). Attached to the covers with the same screws are stator bushings of the electric motors driving the rotor. The stator is a laminations assembly of 341 electrotechnical steel laminations, fitted and flared on the steel stator bushing (16). The laminations have 42 grooves which house the stator winding made of ПЗВ-2 wire 0.31 mm in diameter.

The diagram of the winding arrangement in the gyro motor stator grooves is shown in Fig. 7.

Pressed in the rotor fly wheel are squirrel cages which are 341 electrotechnical steel laminations placed between copper rings joined by 19 copper rivets passing through the grooves of the laminations.

Attached to the gyro motor casing are two brackets (17, Fig. 6) with the balancing screws (18) screwed in them. An assembly of contact springs on the sleeve (19) is installed on one of the brackets.

The balance weight (20) is fitted to the upper part of the gyro assembly casing and the liquid level switch (1) is installed on the boss (21) at the lower part of the gyro assembly casing.

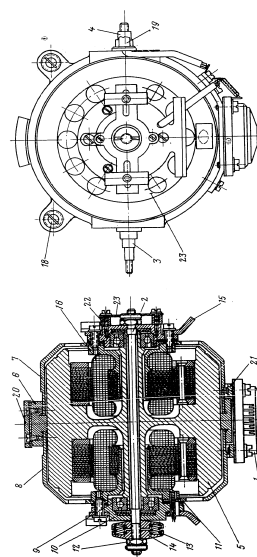


FIG. 6. Gyro Assembly Design

- 1 - liquid level switch; 2 - clamp; 3 - pivot; 4 - pivot; 5 - rotor; 6 - ring; 7 - cover; 8 - cover; 9 - ball bearing; 10 - ball bearing cap; 11 - gaskets; 12 - nut; 13 - spring; 14 - slide block; 15 - stop; 16 - stator bushing; 17 - bracket; 18 - balancing screw; 19 - sleeve; 20 - balance weight; 21 - boss; 22 - sleeve; 23 - bimetallic plate.

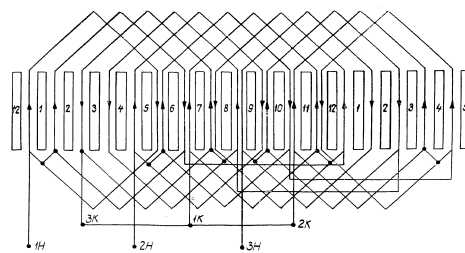


Fig.7. Arrangement of Windings in Gyro Motor Stator Grooves

H_1, H_2, H_3 - Prime ends of first, second and third phases respectively.
 K_1, K_2, K_3 - Final ends of first, second and third phases respectively.

Though the gyro motor is of symmetrical construction, its centre of gravity may be shifted (unbalance) relative to the gyro motor suspension axis when ambient temperature changes from $+50$ to -60°C .

Installed on the sleeve (22) is the bimetallic plate (23) of invar-steel with lead weights which may be shifted towards the centre of the plate and moved apart towards the plate edges to compensate a possible unbalance.

With any change in ambient temperature the bimetallic plate bends, the weights fitted on it approach the gyro assembly suspension axis or move away from the latter thus shifting the common centre of gravity of the gyro assembly and plate. The more is the distance over which the weights are moved ($A > B$), the more is the gyro assembly centre of gravity shift.

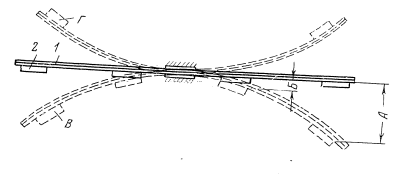


Fig.8. Bimetallic Plate Operation Diagram

1 - Bimetallic plate; 2 - weight.

If the plate is attached with the Invar surface down, at a temperature above zero it is bent to the "B" position. If the plate is installed with the Invar surface up, it is bent to the "I" position at a temperature above zero.

Position of the weights and plate centre of gravity is so that any shift of the gyro assembly centre of gravity is compensated by shifting the weights on the bimetallic plate.

Principle Data of Gyro Assembly

1. Rotor inertia moment
2. Speed of rotor rotation
3. Gyroscope kinetic moment
4. Rotor diameter
5. Inner diameter of rotor

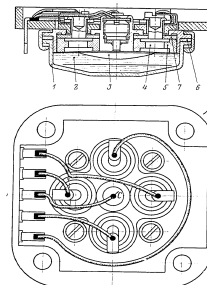


Fig. 9. Liquid level switch

1 - reservoir; 2 - current-carrying liquid; 3 - air bubble;
4 - electrode; 5 - insulating bushing; 6, 7 - pins.

Two sliding contacts are connected to the contact rings of the differential reaction torque meter. The carbon lining of the switch is connected to one of the gyro motor power supply phases.

When the gyro assembly axis is in the horizontal plane, the air bubble overlaps both electrodes equally, the electric resistance between the reservoir and both electrodes being equal. The erecting torque in this case is zero.

When the gyro assembly axis is deflected from the horizontal plane, one of the electrodes is covered by the liquid, and the other

is isolated from the liquid and, thus, from the reservoir by the air bubble.

In this case current in the circuit controlled by the first contact increases, and in the circuit controlled by the second contact current decreases. During this, the erection torque motor produces a torque of the certain direction causing precession of the gyro axis towards the horizontal plane.

Main technical data of the liquid level switch:

1. Sensitivity 5-10 minutes of arc.
2. Maximum permissible current flowing through one contact -- not more than 60 mA.
3. Minimum resistance between the contact covered with liquid and the switch casing when the switch is tilted at an angle exceeding 30 min. of arc is not more than 150 ohms.
4. Maximum resistance between the opposite contact (mentioned in step 3) and the switch casing under the same conditions is not less than 5000 ohms.

NOTE: This liquid level switch is similar to switches used in ATK-47E, ATW-I, AUF-2 artificial horizons.

MM-0,5 ELECTRIC MOTOR WITH REDUCTION GEAR

The motor (19) with the reduction gear is located on the top of the gimbal ring (See Fig.4). The reduction gear consists of four pairs of spur gears installed between the two plates (1 and 2, Fig.10); attached to the plate (2) is the low-inertia, two-phase induction motor model MM-0,5 (3) whose general view is shown in Fig.11. The reduction gear is secured to the gimbal ring by means of the other plate.

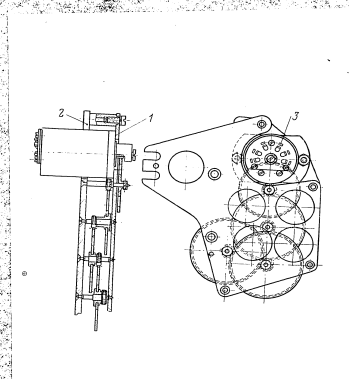


Fig. 10. AMM-0,5 Electric Motor with Reduction Gear

1 - Upper plate; 2 - lower plate; 3 - AMM-0,5 electric motor.

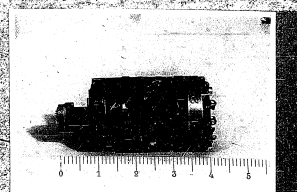


Fig. 11. AMM-0,5 Electric Motor

The gear ratio from the motor to the final pair of gears is as follows:

$$\frac{0.6}{25.2} \cdot \frac{5}{30} \cdot \frac{5}{30} \cdot \frac{5}{30} = \frac{1}{1512}$$

The total gear ratio from the AMM-0,5 motor to the output is 10584.

Principal Data of AMM-0,5 Electric Motor

1. Maximum static torque - not less than 5.5 gr/cm.
2. Idle speed - not less than 13000 r.p.m.
3. Field winding resistance - 70 ± 7 ohms
4. Resistance of each control winding - 260 ± 26 ohms

NOTE: Similar electric motors are used in the AMM-1 and AMM-2 units.

HORIZONTAL ERECTION TORQUE MOTOR

(Fig. 12, 15)

The horizontal erection torque motor is an asynchronous reversible two-phase motor with short circuit rating.

The horizontal erection torque motor consists of laminations assembly in the form of a cylinder of 34T electrotechnical steel with remanent induction.

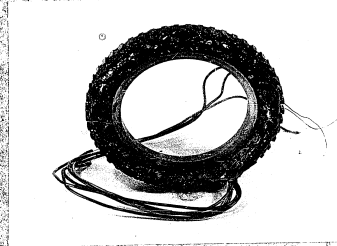


Fig. 12. General View of Horizontal Erection Torque Motor Rotor

The rotor windings (1) (one main winding and two control windings) are laid in the rotor laminations assembly grooves. The windings are made of MSB-2 copper wire insulated by vitaflex.

The main winding is made of 0.1 mm. dia. wire, and the control windings are of 0.07 mm. wire.

The diagram of windings arrangement in the rotor laminations assembly groove is given in Fig. 14.

The stator (1, Fig. 15) consists of an electrotechnical steel laminations assembly (similar to the rotor laminations assembly) and a short-circuited squirrel cage cast of AL3 aluminum alloy.

The stator laminations are so assembled that they form a groove adapted for end to end.

This stator structure precludes a possible "sticking" of the stator to the rotor.

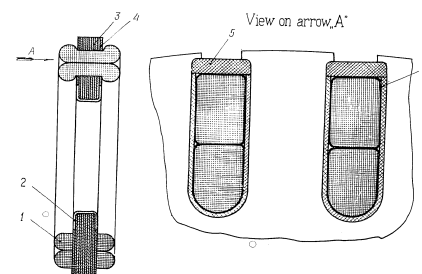


Fig. 13. Design of Horizontal Erection Torque Motor Rotor.

1 - Windings; 2 - frame; 3 - laminations assembly; 4 - end Lamination; 5 - wedge; 6 - groove insulation

Principal Data of Horizontal Erection Torque Motor

1. Power supply 36 V, 400 c.p.s., three-phase a.c.
2. Erection torque 12-15 gr.-cm.
3. Stator (fit) outer diameter 70 mm.
4. Stator inner diameter 64.2 mm.
5. Air clearance 0.15-0.18 mm.
6. Motor height 13 mm.
7. Rotor (fit) inner diameter 39 mm.
8. Number of stator rods 102
9. Number of rotor grooves 52
10. Main winding resistance 400 ohms
11. Control winding resistance 600 ohms

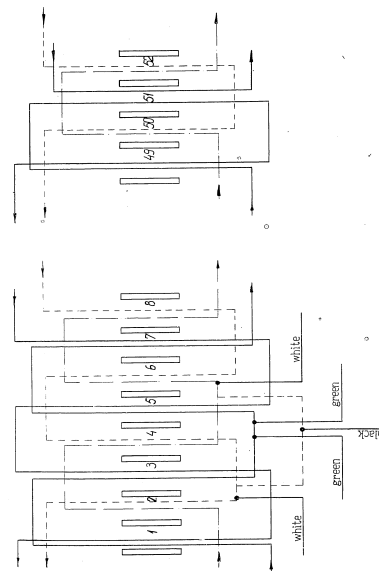


Fig. 14. Arrangement of Windings in Grooves of Horizontal Direction Torque Motor Rotor

H0-1, H0-2 - Prime ends of first and second additional windings respectively;
 H0-1, H0-2 - Final ends of additional windings;
 H0-1 - Prime end of main winding;
 H0-2 - Final end of main winding.

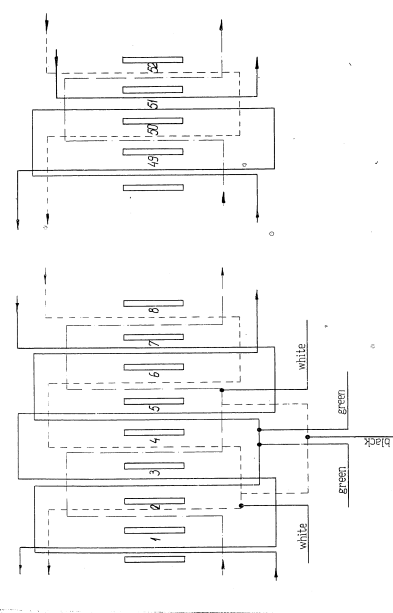


Fig. 14. Arrangement of Windings in Grooves of Horizontal Section Torque Motor Rotor

H10-1, H10-2 - Prime ends of first and second additional windings respectively;
 H10-1, H10-2 - Final ends of additional windings;
 H00 - Prime end of main winding;
 H00 - Final end of main winding.

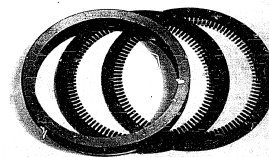


Fig. 15. Horizontal section of motor.

1 - stator, 2 - stator laminations.

MINUTE 15.001 N 10.001 N 10.001 N

(Fig. 16)

Similar to the horizontal section of the motor, the minute section for the motor shows the stator and rotor. The motor (1) is inside the stator (2).



Fig. 16. Minute section of motor.

1 - stator, 2 - rotor.

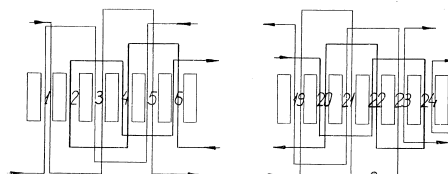


Fig. 17. Arrangement of Windings in Grooves of Azimuth Erection Torque Motor Stator.

1 - Control winding; 2 - main winding.

The rotor consists of a laminations assembly cast at a pressure with AT3 aluminium alloy so that this material forms a squirrel cage which consists of two rings and seventeen rods filling the slanted grooves of the stator laminations assembly.

The azimuth erection torque motor stator consists of a 341 electrotechnical steel laminations assembly flared in a brass frame.

The main and control windings of the stator are laid in the twenty four grooves of the laminations assembly.

Both windings are of HSB2 copper wire 0.07 mm. in diameter with varnished insulation. The windings arrangement in the stator grooves is shown in Fig. 17.

Principal Data of Azimuth Erection Drive Motor

1. Power supply 36 V, 4.0 A.c.s., three-phase
2. Erection torque at 15 V
supplied to control winding not less than 4.5 gr.-cm.
3. Stator outer (fit) diameter 49 mm.
4. Stator inner diameter 38 mm.
5. Air clearance 0.35 mm.
6. Motor height 14 mm.
7. Number of stator grooves 12.
8. Number of rotor poles 12.
9. Main winding resistance 4.00 ohms.
10. Control winding resistance 100 ohms.

FUNCTION DESCRIPTION

Fig. 12 shows the general view of the potentiometer which is used for determining the azimuth location of the target. The potentiometer consists of the stator (Fig. 12, 1) and the rotor (2).

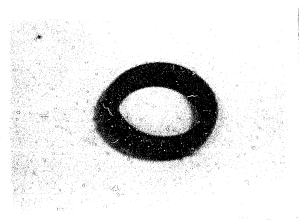


Fig. 12. Output Potentiometer

The winding is made of ПМ-10 platinum-iridium alloy enamelled wire of 0.08 mm. This material possesses the properties necessary for a potentiometer winding: high specific resistance, good corrosion-resisting qualities, and it does not cause any burning when operating in contact with the ПМ-18 palladium-iridium alloy wiper.

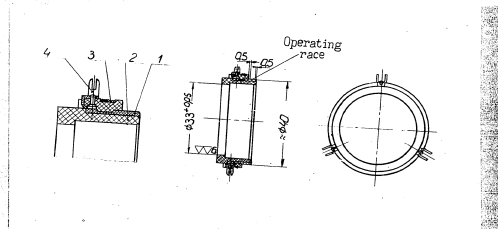


Fig. 19. Potentiometer Design

1 - Frame with winding; 2 - potentiometer base; 2 - binding;
4 - contact.

The frame with the winding is installed on the potentiometer base (2) and attached with the binding (3) whose rim enters the groove in the frame and tightens the winding wire. The whole potentiometer is impregnated with 1154 varnish, the insulation is cleaned from the operating race and the latter is polished.

Three tappings located 120° apart are soldered to the three contacts (4) secured on the binding.

Principal Data of Potentiometer

1. Power supply 27 V $\pm$ 10% D.C.
2. Angle between power supply wipers 180°
3. Winding wire MM3-10 ϕ 0.08 mm.
4. Resistance between contacts 270 ohms $\pm$ 10%
5. Operating race diameter 40 mm.
6. Potentiometer height 14.5 mm.
7. Nonuniform winding space, not more than 0.6°

GIMBAL RING ASSEMBLY IN CASING

The gyro assembly (1, Fig. 20) is supported in the outer gimbal ring (2) by A1000095Y radial ball bearings.

The ball bearings are ϕ 5x ϕ 13x 4 in size. The ball bearings friction moment is in the range of 0.1-0.3 gr.-cm.

The ball bearings are fitted in the caps (3) by means of the nuts (4).

End play of the gyro assembly (1) in the ring (2) is adjusted by the gaskets (5) placed under the flanges of the caps (3).

The azimuth erection torque motor rotor (6) is installed on the gyro assembly shaft, and the azimuth erection torque motor stator (8) is attached to the ring in the frame (7).

Attached with three screws to the top of the ring (2) is the MM-0.5 electric motor with the reduction gear (9) whose output gear is engaged with the gear (10) installed on the shaft (11) which passes through the hollow shaft (12) of the gimbal ring.

This shaft carries the slip rings (13) to carry the wipers (14), the output potentiometer (15) and has secured the textile strap with the wiper holder and the

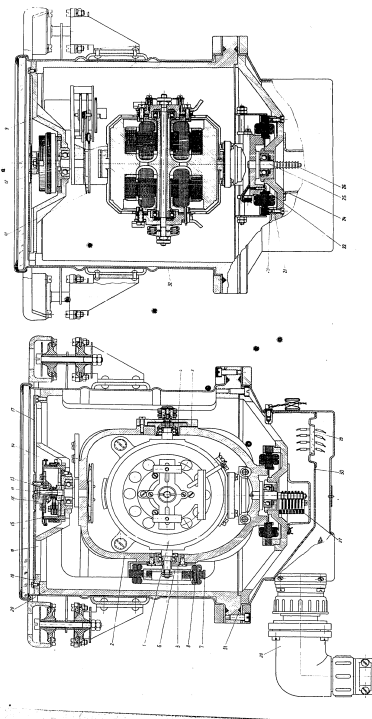
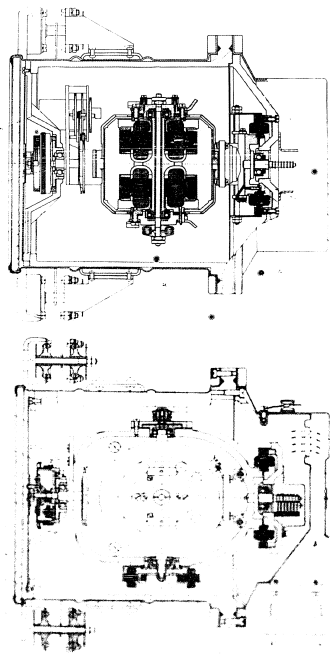


Fig. 10. Directional gyro (transmitter) design

- 1 - Gyro assembly; 2 - ring; 3 - ball bearing cup; 4 - nut; 5 - gasket; 6 - azimuth erection torque motor rotor; 7 - frame; 8 - azimuth erection torque motor stator; 9 - ALA-0,5 electric motor with reduction gear; 10 - gear; 11 - shaft; 12 - gimbal ring shaft; 13 - slip rings; 14 - potentiometer wipers; 15 - output potentiometer; 16 - bushing; 17 - dial; 18 - rings with indexes; 19 - upper frame; 20 - case; 21 - horizontal erection torque motor rotor; 22 - clamp ring; 23 - horizontal erection torque motor stator; 24 - lower flange; 25 - lower shaft; 26 - slip rings; 27 - block; 28 - plug connector; 29 - glass insulators; 30 - housing cover; 31 - rubber cord; 32 - housing.



74-10	Directional Gyro (Transmitter) Design
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- 1 - type number; 2 - pin; 3 - ball bearing; 4 - nut; 5 - washer; 6 - clutch spring
7 - screw; 8 - pin; 9 - clutch spring torque meter; 10 - 100-kg electric
balance; 11 - nut; 12 - clinal ring; 13 - slip ring;
14 - potentiometer; 15 - output potentiometer; 16 - bushing; 17 - dial; 18 - ring with
scales; 19 - copper plate; 20 - base; 21 - horizontal spring torque meter; 22 - clamp
for base; 23 - clamping bracket; 24 - lower frame; 25 - lower shaft;
26 - plug connector; 27 - base for dial; 28 - clamping cover;
29 - nut; 30 - pin.

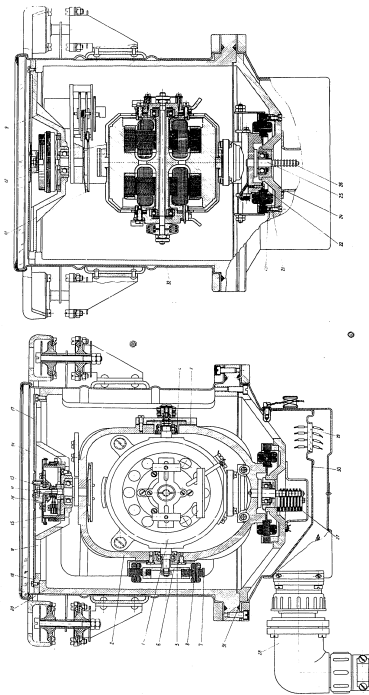


FIG. 20. Directional Gyro (Transmitter) Design

- 1 - Gyro assembly; 2 - rim; 3 - ball bearing cup; 4 - nut; 5 - gasket; 6 - azimuth erection torque motor rotor; 7 - frame; 8 - azimuth erection torque motor stator; 9 - AM-0,5 electric motor with reduction gear; 10 - gear; 11 - shaft; 12 - gimbal ring shaft; 13 - slip rings; 14 - potentiometer wipers; 15 - output potentiometer; 16 - bushing; 17 - dial; 18 - rings with indexes; 19 - upper frame; 20 - case; 21 - horizontal erection torque motor rotor; 22 - clamp rings; 23 - horizontal erection torque motor stator; 24 - lower frame; 25 - lower shaft; 26 - slip rings; 27 - block; 28 - plug connector; 29 - glass insulators; 30 - housing cover; 31 - rubber cord; 32 - housing.

The dial is graduated with 360 divisions each representing 1° and marked with figures for each 30° , the letters N, E, S, W (N, E, S, W) being painted for each 90° . Two fixed indexes are painted on the ring (18). The instrument indications are read by mutual position of the dial and indexes on the case. The general view of the unit is shown in Fig. 27).

The potentiometer (15) is secured to the upper flange (19) of the case (20).

The horizontal erection torque motor is installed on the bottom of the unit. The motor rotor (21) is attached to the ring (2) by means of the clamp ring (22), and the stator (23) is installed in the lower flange (24). The seven slip rings (25) are glued to the lower hollow shaft (25) of the ring. Seven pairs of contact wipers mounted on the block (27) contact the slip rings.

Power is supplied to the directional gyro (transmitter) through the angular 14-pin plug connector (28) and glass insulators (29) soldered in the housing cover (30) separating the sealed section on the unit from the nonsealed section.

Power supply to the gyro motor and liquid level switch as well as signals from the liquid level switch to the control windings of the gyroscope horizontal erection torque motor are transmitted through a group comprising five pairs of contacts.

The directional gyro (transmitter) is sealed with the round rubber cord (31) placed under the unit housing (32) and under the housing cover (30) in which the glass insulators (29) are soldered. Used in the directional gyro electrical wiring is MMB and MILB wires with insulating coatings of different colours in accordance with the wiring diagram given in Fig. 21.

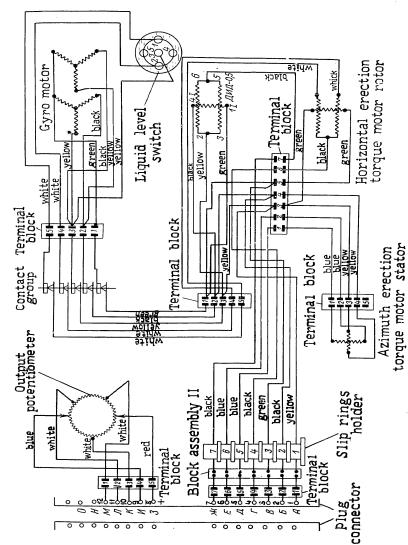


Fig. 24. Directional Gyro (Transmitter) Wiring Diagram

SHOCK MOUNT ASSEMBLY

The directional gyro (transmitter) shock mount assembly comprises the collar (1, Fig.22), to which are attached four brackets (2), carrying four 271C49-1-3 rubber shock absorbers (3), and plate 4 by which the unit is attached to the navigator's table.

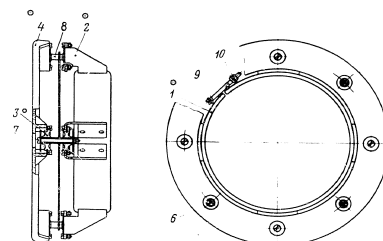


Fig.22. Directional Gyro Shock Mount Design

1 - Collar; 2 - bracket; 3 - shock absorber; 4 - plate; 5 - bracket; 6 - self-locking nut; 7 - screw; 8 - bushing; 9 - screw; 10 - nut.

The brackets (5) and self-locking nuts (6) are attached to the plate. The 271C49-1-3 rubber shock absorbers are secured to the brackets (5). The plate (4) is attached to the collar (1) by means of four screws (7) clamping the shock absorbers via the bushing (8). The collar is tightened on the housing with the two screws (9) and nuts (10).

2. CONTROL PANEL

The control panel (Fig.23) is designed:

1. To control the inverter power supply;
2. to supply voltage to the control winding of the directional gyro azimuth erection torque motor.

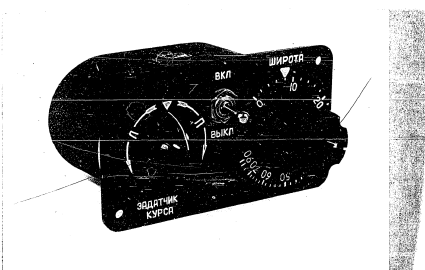


Fig.23. Control Panel

3. To control the directional gyro dial turning.

Installed in the control panel are two potentiometers coupled in the following manner:

the shaft (3) of the potentiometer (4) passes through the hollow shaft (1) of the potentiometer (2, Fig.24); the wipers are fitted to the above shafts. The potentiometers assembly is given in Fig.25.

Both potentiometers are connected in parallel to a 36 V, 400c.p.s. A.C. circuit.

The wipers of the potentiometers are interconnected via the control winding of the gyroscope azimuth erection torque motor and together with the latter they form the diagonal line of the bridge formed by the potentiometer windings (Fig.26).

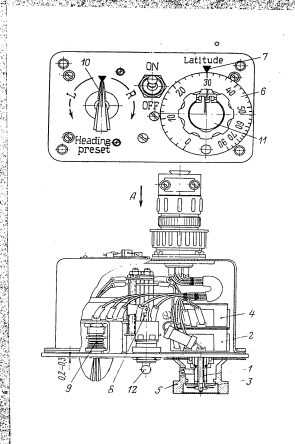


Fig. 24. Control Panel Device

1 - hollow shaft; 2 - latitude potentiometer; 3 - spring; 4 - rheostat; 5 - switch; 6 - index; 7 - shaft; 8 - rheostat; 9 - spring; 10 - reading press; 11 - switch; 12 - switch.

When the potentiometer finger has reached its position, the bridge is released in its diagonal line to turn the azimuth correction to the azimuth correction produced by the error.

In order to obtain such a torque from the azimuth erection torque motor, that would make the gyroscope precess at a speed equal to the vertical component of the vector of earth's rotation angular velocity at a given place, turn the knob (5) with the dial (6, Fig.24) so that the index (7) coincides with the scale division corresponding to the latitude of the aircraft position. In this case the wiper of the potentiometer (2) linked with the knob (5) will turn too.

The electric bridge will come out of balance, current will flow in the azimuth erection torque motor control winding and produce a torque about the axis of the gyro inner gimbal ring.

The torque imposed will make the gyro precess in the required direction and at the required speed.

Efficiency of the latitude correction that should be equal to the speed of earth's rotation, i.e. 15 deg./hr is adjusted by the trim rheostat (8).

When the directional gyro has been in operation for an extended period of time, it may become unbalanced due to wear and deformation of its parts.

To compensate the torque about the inner gimbal ring axis due to unbalance, additional voltage is supplied to the azimuth erection torque motor control winding by turning the wiper of the potentiometer (4).

The directional gyro dial turn control mechanism is installed in the control panel. This mechanism consists of a wiper held in the middle position by the spring (9) and four segments cut in the circuit via resistors (Fig.26).

When the knob (10) is turned to the right or to the left through a small angle, the wiper rigidly linked with the knob and connected to the MA-0.5 electric motor control winding circuit over the one of the segments which is connected to the A.C. phase via a resistor

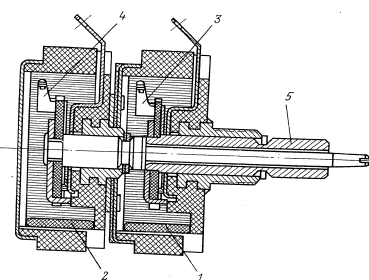


Fig. 25. Potentiometers Assembly

1 - Latitude potentiometer; 2 - correction potentiometer; 3 - latitude potentiometer wiper; 4 - correction potentiometer wiper; 5 - hollow shaft.

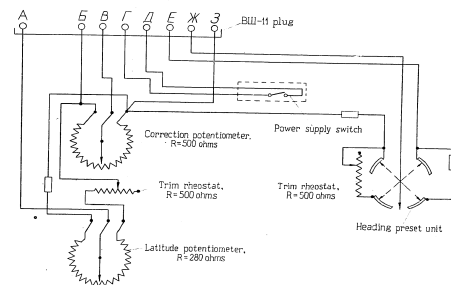


Fig. 26. Control Panel Wiring Diagram

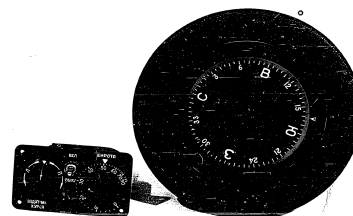


Fig.27. General View of Directional Gyro (Transmitter) with Control Panel

During this the dial rotates at a low speed. When the knob (10, Fig.24) is turned through a larger angle, the resistors in the AMA-0.5 electric motor control winding circuit are cut off and the dial rotates at a higher speed. The trim rheostat (8) is provided in the control panel circuit to adjust the low speed of the dial rotation to the left.

If it is required to turn the dial through a large angle, rapidly turn the dial by turning the knob (10) through a large angle, and then establish a low speed of the dial rotation to accurately set it against the indexes.

The wiper is automatically returned to zero position by the spring (9).

The general view of the directional gyro with the control panel is given in Fig.27.

2. MK-50PB ERECTING CUT-OUT SWITCH

The MK-50PB erecting cut-out switch (Fig. 20) is designed to cut-off the gyro units erection system when the aircraft performs turns or other maneuvers with an angular speed exceeding the certain value.

Operation of the switch is based on the tendency of a gyro with two degrees of freedom to match the vector of the gyro rotation angular speed with the vector of the angular speed of the gyro base rotation.

In the erecting cut-out switch the gyro is held in the centre position by springs.

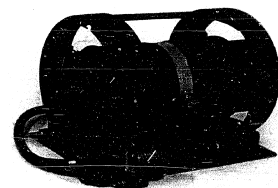
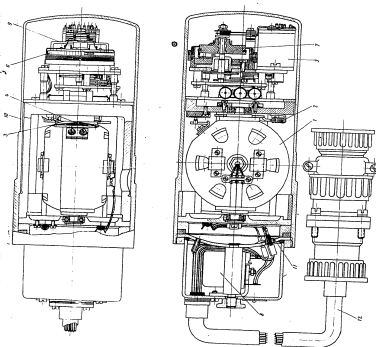
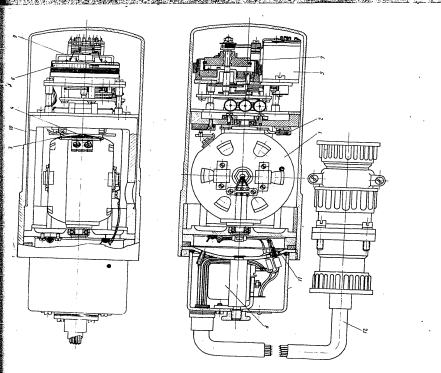


Fig. 20. MK-50PB Erection Cut-out Switch

At an angular speed the gyro tilts overriding the force of the springs and engages the mechanism which breaks the erection circuit in a certain period of time after the angular speed begins noting. Due to this the erection system is cut out only at a steady angular speed (at oscillation and shocks in flight the erection system is not cut-off).



1 - electric motor; 2 - electric motor; 3 - electric motor; 4 - electric motor; 5 - electric motor; 6 - electric motor; 7 - electric motor; 8 - electric motor; 9 - electric motor; 10 - electric motor.



1 - contact spring, 2 - contact spring, 3 - MM-05 electric motor,
4 - contact spring, 5 - contact spring, 6 - contact spring, 7 - contact spring,
8 - contact spring, 9 - contact spring, 10 - contact spring.

The sectional view of the erecting out-out switch is given in Fig.29. The schematic diagram is in Fig.30.

A gyro having two degrees of freedom is the main component of the BK-53PB erecting out-out switch.

The electric gyro motor of the gyroscope (1, Fig.29) is an asynchronous three-phase motor supplied with 36 V, 400 c.p.s.A.C.

One degree of the gyroscope freedom (angle of turn about the gyro assembly suspension axis) is restricted by the springs (2).

The springs (2) are prestressed and this removes play in the moving system ensuring stable operation of the switch.

The erecting system of the gyro units is out-out as follows:

At an angular speed, the gyroscope (1), overriding the resistance of the springs, turns about its suspension axis, tending to match the kinetic moment vector with the vector of the angular velocity of the base on which the switch is installed.

In this case the wipers (3) fitted on the gyro assembly contact one of the segments (4) installed on the gyro assembly case and close the circuit of one of the $110V-0.5$ electric motor (5) control windings.

The electric motor starts rotating and via the reduction gear rotates the disc (7) with contact plates. When the contact disc turns through a required angle, it closes the circuit of the electromagnetic relays (8). The relays are actuated and open (or close) the contact groups which are connected in the gyro erection circuits.

When the disc (7) turns, the wipers (9) of the potentiometer turn simultaneously. Voltage supplied to the other control winding (terminals 3,5; see Fig.30) of the $110V-0.5$ electric motor creates a torque opposite to that produced by the current flowing through the first control winding (terminals 2,6).

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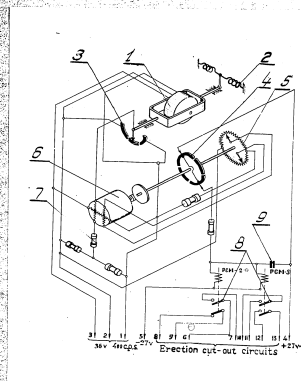


Fig. 20. BK-53PB Erection Cut-Out Switch Schematic Diagram

- 1 - Gyroscope; 2 - springs; 3 - contact segments; 4 - contact disc;
 5 - potentiometer; 6 - electric motor with reduction gear;
 7 - resistor; 8 - PCM-2 and PCM-3 relay contacts; 9 - spark-quench capacitor.

While the contact disc and wipers are turning, the voltage picked up by the wipers from the potentiometer rises and the current flowing through the windings of the terminals 3 and 5 increases too, thus increasing the torque.

The electric motor stops rotating when the torque created by the control windings becomes balanced.

After the angular speed action ceases, the springs (2) return the gyroscope (1) to the initial position, the circuit of the control windings of the terminals 2, 6 is open and the electric motor actuated by current flowing through the windings of the terminals 3, 5 returns

the contact disc to the initial position.

The circuit of the relay (8) breaks, the relay contacts close (or open) setting the gyro erection system in operation.

The switch mechanism is enclosed in a sealed case. Electric power is supplied to the switch through glass insulators that do not unseal the switch. One BK-53PB switch can cut out the erection mechanism of four gyro units simultaneously.

The switch is attached to the aircraft structure through a spring shock mount.

Principal Data of BK-53PB Switch

1. Erection cut out angular velocity 0.3 deg/sec.
2. Cut out delay time from 3 to 15 sec.
3. Maximum current in erection cut out circuit 200 mA
4. Power supply 36 V, 400 c.p.s. A.C. and 27 V $\pm$ 10% D.C.
5. Alternating current drawn not more than 0.45 a
6. Direct current drawn not more than 0.2 a
7. The switch can serve four erection circuits simultaneously:
breaks three circuits and closes one circuit when angular velocity exceeds 0.3 deg/sec.
8. Operating temperature range from +50 to -60°.
9. The switch reliably operates at vibration overload of 2.5 G, within a frequency range from 20 to 80 c.p.s.
10. Weight 2600 gr.

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4. HT-70 INVERTER

The HT-70 inverter (Fig.31) serves to convert 27 V direct current of the aircraft electrical system into 36 V, 400 c.p.s. three-phase alternating current.

The inverter consists of a D.C. electric motor of compound excitation and a three-phase A.C. generator excited by a permanent magnet. The electric motor rotor and generator have a common case made of aluminium alloy. The generator rotor and electric motor armature are mounted on a common shaft.

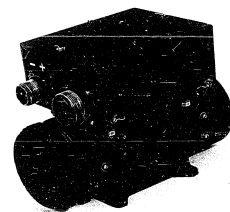


Fig.31. HT-70 Inverter

The shaft carries a centrifugal regulator with contact segments; the regulator controls A.C. frequency.

A filter box is located on the inverter case. The filter box houses the following units:

- a) a contactor for remote control of the motor from the control panel;
- b) the inverter radio noise filter.

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Power cables are connected through standard plug connectors installed on the filters box. More detailed information on the HT-70 inverter is given in its description.

Principal Data of HT-70 inverter

1. Supply voltage 27 V
2. Current drawn not more than 3.2 a
3. Output power 70 VA
4. A.C. load 1.12 a
5. A.C. voltage 36 V
6. A.C. frequency 400 c.p.s. $\pm 2\%$
7. Power factor (lagging) 0.6
8. Rotor speed 12000 r.p.m.
9. Weight of inverter
with box not more than 4.2 kg.
10. Service life 400 hours
11. Operating temperature
range from $+50^{\circ}$ to -60°C
12. Service ceiling 20000 m.

5. HMK-49 INDICATOR

The HMK-49 indicator (Fig.32) is used as a HMK-52 directional gyro repeater and is usually installed on the pilot's instrument panel.

The HMK-49 indicator is a three-phase magnetoelectric ratiometer.

Its moving assembly consists of the magnet (1, Fig.33) pressed on the shaft (2), to one end of which the pointer (3) is attached. The magnet rotates inside the ratiometer stator (4) having a three-phase winding that consists of six coils wound around a toroid of permalloy rings.



Fig.32. IUK-49 Indicator

The ends of the windings are so connected that every two diametrically opposite coils form one phase.

Thus all the six coils form three phases spaced on (an annular) magnetic circuit 120° apart. The windings are star connected. The terminals of the phases are soldered to the three slip rings (5) contacting the wipers (6). Each wiper is soldered to the column (7) pressed in the bottom of the indicator case. Each column is connected to the pin (8) of the plug connector (9).

The whole mechanism of the instrument can be turned relative to the case by means of the knob (10), which is installed on the same shaft with the gear (14) meshed with the gear (13) via the idle gear (12); the gear (13) is rigidly linked to the stator body. Power is supplied to the instrument through the three-pin plug connector (9). By rotating the knob (10), turn the dial (14) so that the dial division corresponding to the desired direction of flight is placed under the fixed heading marker (15) vertical line on the top of the instrument.

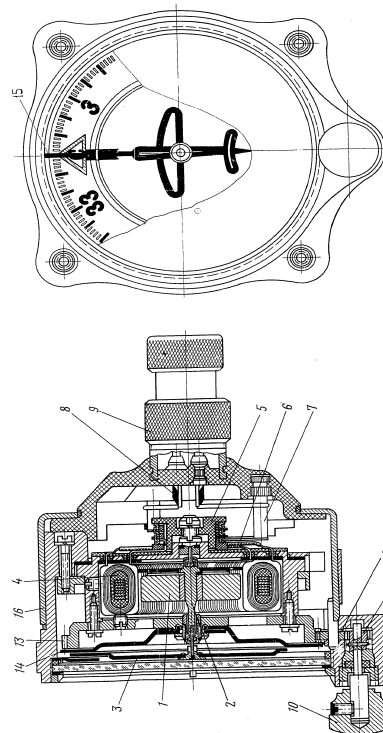


Fig. 22. Indicator Design

1 - Magnet; 2 - shaft; 3 - pin; 4 - stator; 5 - slip ring assembly; 6 - wiper; 7 - column;
8 - pin; 9 - plug connector; 10 - knob; 11 - gear; 12 - idle gear; 13 - gear; 14 - dial;
15 - bearing; 16 - screen.

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The stator (4) rotates together with the dial turned by the knob.

Interaction between the stator and magnet make the magnet with the pointer fitted on the same shaft rotate together with the stator, i.e. the pointer follows the rotating dial indicating the aircraft heading. If the dial is turned as described above when the aircraft is flying in the desired direction, the pointer of the indicator points up at the vertical triangle-heading marker.

Deflection of the miniature aircraft to the right and to the left from the heading marker shows the required direction of a turn to restore the aircraft heading.

In addition, the heading marker relieves the pilot of the need to remember the required direction of flight (the aircraft heading).

The screen (16) is provided to lessen the indicator magnetic field influence on a magnetic compass; the screen also serves as a protective housing.

6. JUNCTION BOX

The electric connections of the directional gyro set units are concentrated in the junction box (Fig.34).

The junction box facilitates detecting troubles, is used for cutting off a faulty circuit and testing separate units in operation.

The case and case cover are made of aluminium.

The cover is attached to the case with four fasteners.

The aluminium plate (3, Fig.35) is fitted on the inner side of the cover. The connections diagram of the set is made on this plate by a photochemical method.

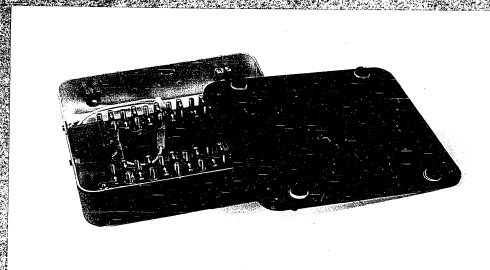


Fig. 34. Junction Box

Inside the box there is a group of two plastic terminal blocks, each having ten terminals.

The terminal blocks are installed on the case bottom. An aluminium plate with an identification letter is attached to one of the terminal bolts of each block, as shown in Fig. 35.

The terminal bolts (5) of the block are separated from each other by lugs that prevent the wire eyes turning on the terminals. Some of the terminal groups are interconnected by the jumpers (6) which serve to connect a certain number of wires. The junction box weight is not more than 0.35 kg.

7. MAIN CHARACTERISTICS OF HIR-52 DIRECTIONAL GYRO

1. Indication stability	2° per hour
2. After-turn error	not more than 0.5°
3. Remote transmission accuracy	2°
4. Operating temperature range	from -50° to +50° C.
5. D.C. power supply	27 V ± 10%
6. Power consumption	10-15 W
7. Weight	0.35 kg

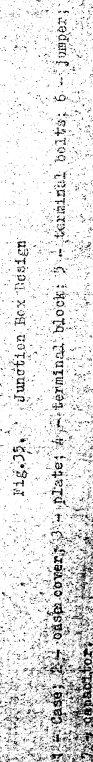


Fig. 35. Junction Box Design

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6. Time required for gyro to be ready for operation not more than 20 min.
7. Weight of directional gyro set (without inverter) 10 kg.
8. III-70 inverter weight 4.2 kg.

VI. INSTALLING THE IIR-52 DIRECTIONAL GYRO SET IN AIRCRAFT

Shielded cables with grounded braidings are used for wiring the directional gyro set according to the cording and wiring diagrams (Figs. 26 and 37).

The directional gyro (transmitter) is installed on the navigator's table or in the fuselage on a special shock mount. When the aircraft is in level flight the instrument dial should be in the horizontal plane.

The control panel must be installed near the directional gyro so as to enable the navigator to observe the directional gyro dial when turning the heading preset knob on the control panel.

The erecting cut-out switch must be installed so that its longitudinal axis is in the horizontal plane, and the letter "E" painted on the unit case is on the top.

The IIR-49 indicators must be installed on a vertical instrument panel or on a bracket in a place affording good readability of the indicators and where an overload does not exceed 1.5 g.

The junction box must be installed in the aircraft fuselage at a place accessible for ringing out the circuits.

The inverter is installed in the level position and secured to the aircraft structure by four M5 screws through the holes in the support.



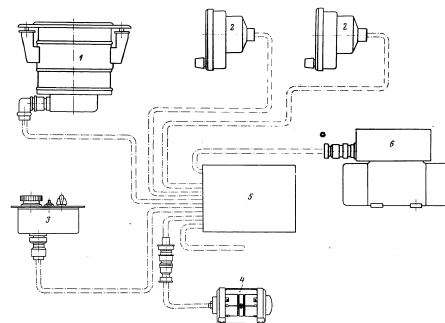


Fig. 37. HMK-52 Directional Gyro Cording Diagram

- 1 - Directional gyro (transmitter); 2 - HMK-49 indicator;
 3 - control panel; 4 - H6-53PB erasing out put switch;
 5 - junction box; 6 - H1-20 inverter.

The inverter and filter box are designed to operate without shock absorbing devices under normal operating conditions.

The inverter is connected to the D.C. circuit through HP20H24AC two-pin plug connectors. Plus is connected to the pin marked "21", and minus - to the pin marked "22".

Alternating current conducted through a HP20H5612 five-pin plug connector.

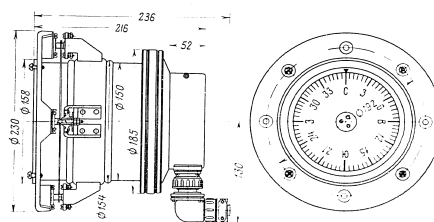


Fig. 38. Overall and Installation Dimensions of Directional Type Transmitter.

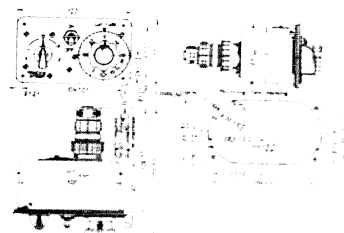


Fig. 39. Overall and Installation Dimensions of Control Panel.

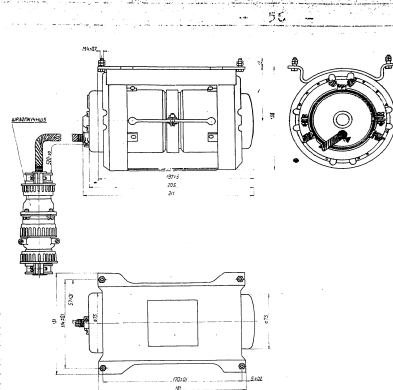


Fig. 40. Overall and Installation Dimensions of BK-53PE Erecting Cut-Out Switch

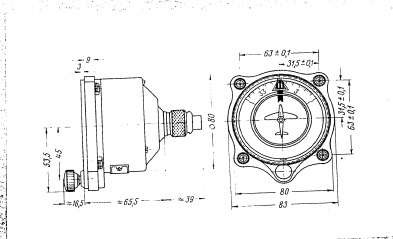


Fig. 41. Overall and Installation Dimensions of BK-43 Indicator

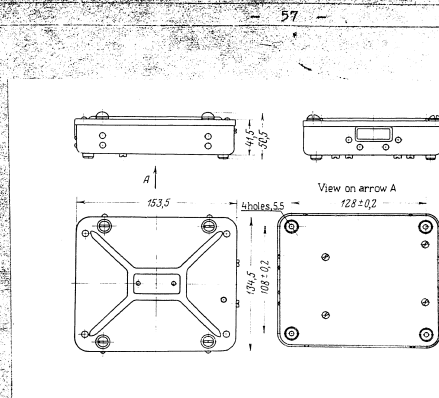


Fig.42. Overall and Installation Dimensions of Junction Box



Overall and Installation Dimensions of JB-70 Inverted.

The inverter is connected in the circuit through a starting capacitor inserted in the box.

No protection of the inverter from overload and short circuiting is provided and therefore it must be done in the control panel.

The HX-52 directional gyro units attachment points must be so chosen that vibration does not exceed the following values:

At a vibration frequency of 20 to 40 c.p.s. the amplitude should not exceed 1 mm.

At a vibration frequency of 40 to 80 c.p.s. the vibration amplitude should not exceed 2 mm.

The overall and installation dimensions of the units are given in Figs. 15, 16, 17, 18, 19 and 20.

VII. CHECKING THE HX-52 DIRECTIONAL GYRO SET ALFIELD CONDITIONS

Setting point of the directional gyro unit is determined by the following conditions:

1. The number for the HX-52 directional gyro unit to become ready for operation.

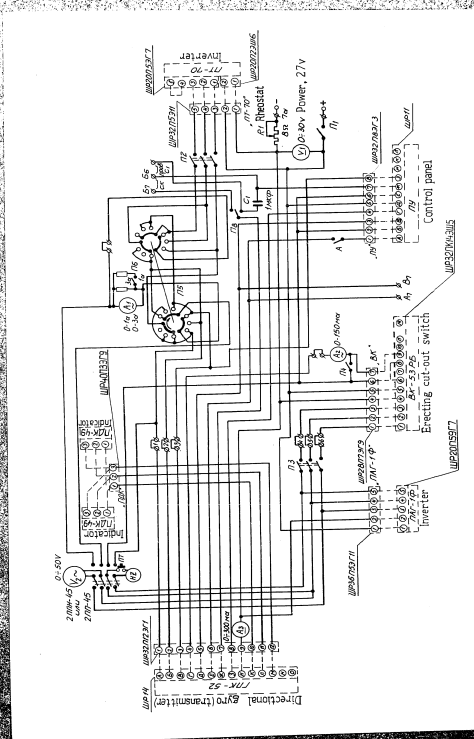
2. Direction given.

3. Instrument reading error.

4. Error of gyro transmission to the HX-52 indicator.

5. Error of directional gyro data transfer to the right and left channels.

6. Error of directional gyro data transfer to the right and left channels.



The ITI-70 and IAP-I Φ inverters are energized by the III switch (Fig. 44). Observing the U_1 voltmeter set 27 V by means of the rheostat connected to the K3-5 terminals.

The H2 switch is turned on; this done, the voltage of $36^{+4.5}_{-1.1}$ V at 400 c.p.s. $\pm 2\%$ is supplied from the ITI-70 inverter to the ITH-52 directional gyro and ITH-52HY control panel; the power supply is checked by the U_2 voltmeter and U_7 frequency meter.

The H3 switch is turned on; in this case the voltage of $36 \pm 10\%$ at 400 c.p.s. $\pm 10\%$ is supplied from the IAP-I Φ inverter to the BK-53PE erecting cut-out switch, which is checked by the U_3 voltmeter and U_8 frequency meter. After energizing the set check the following parameters:

1. Time required for the system to be ready for operation.
This parameter is determined by the time required for the gyro rotor to come up to full speed.

The time is checked from the moment of energizing the set to the moment when the gyro operating current is established. In the ITH-52 directional gyro the current should not exceed 0.8A and in the BK-53PE erecting cut-out switch it should not exceed 0.45A.

Time required for the ITH-52 directional gyro to become ready for operation at normal temperature should not exceed 12 minutes.

2. Gyro rotor axis drift in azimuth (instrument error).

The directional gyro is installed on a bracket of the VIII-48 test unit and then the set is energized.

20 minutes after the set is energized, the latitude of the place where the directional gyro was manufactured is set on the ITH-52-HY control panel, and the correction potentiometer on the

control panel is set in the middle position at which the voltage picked up from the latitude and correction potentiometer wipers is zero.

This voltage supplied to the azimuth corrector torque motor control winding is checked by the ± 1 voltmeter (terminal), connected to the A_7-B_7 terminals on the control panel to test the ± 1 directional gyro. Then the ± 1 terminal of the wiper across the gyro rotor axis drift in azimuth is checked and is set on the ± 1 directional control panel.

With the test unit in the level position the instrument dial is set to one of the four rhumbs by means of the rhumb select knob on the control panel.

Tilt the ± 1 test unit table through 90° to start rocking it with a period of 10 to 15 sec. in a continuous motion for 1.0-2.5 min.

After 30 minutes of rocking, switch off the test unit, return the table to the horizontal position and check the instrument error by observing the mutual position of the dial and fixed scale. Then repeat the test for the other three rhumbs.

The gyro rotor axis drift in azimuth (directional error) for each of the four rhumbs for 30 min. of directional gyro operation should not exceed $\pm 1^\circ$, and for one of the rhumbs a drift up to $\pm 2^\circ$ is permissible, provided the total drift for the four rhumbs is not more than 4° .

If a one-side drift exceeds the above indicated limits, readjust the instrument. To do this, turn the correction potentiometer shaft (D, Fig. 24) located under the cover (1) of the latitude setting knob (5).

If the instrument readings increase, turn the correction potentiometer shaft clockwise through about as many divisions as is the number of degrees by which the instrument readings change for 30 min. If the instrument readings decrease turn the correction potentiometer shaft counterclockwise.

3. Error or remote transmission to HMK-49 indicators.

Set the D.C. switch on the control panel to the "ON" position and, turning the heading preset knob, turn the directional gyro dial through 40° .

Observe the readings of the two HMK-49 indicators. Difference between the readings of the directional gyro and HMK-49 indicators is the remote transmission error on the given heading. This error should not exceed 2° .

4. Directional gyro (transmitter) dial turning speed.

Energize the set. In 20 minutes, when the system becomes operating, turn the heading preset knob 45° to 60° to the right; in this case the instrument dial should turn clockwise and, when the heading preset knob is turned through an angle of 45° to 60° to the left, the instrument dial should turn counterclockwise. The speed of instrument dial turning when the heading preset knob is turned through an angle of 45° to 60° should be within the range of 25 deg./min. to 100 deg./min.

When the heading preset knob is turned through an angle of 120° to 150° (full way) to the right or to the left, the instrument dial should turn clockwise or counterclockwise respectively. The turn speed should not be less than 40 deg./min.

5. Erection cut-out angular speed. Attach the shock-mounted erecting cut-out switch on the YHK-52 test unit so that the letter "E" painted on the instrument case is on the top. Energize the set.

Set an angular speed of 0.3 deg/sec. on the YHK-52 test unit. 12 minutes after energizing the set start the YHK-52 test unit and using a stop watch check the time from the moment an angular speed appears up to the moment when the horizontal erection circuit is open.

The erection circuit breaking will be indicated by a milliammeter showing a current drop to zero. Then stop the turn table and 15-20 seconds after this make a similar test with the turn table rotating in the opposite direction at an angular speed of 0.3 deg/sec.

The YHK-52 directional gyro erection should be cut out in 3.0-15.0 sec. from the moment the angular speed of turn equal to 0.3 deg./sec. appears.

NOTE: In addition to the YHK-52 test equipment the following units must be furnished:

1. Tg-1 tester
2. HAK-49 reference indicator.
3. YHK-52-INV reference control panel.
4. IT-70 inverter.

The directional gyro must be tested without the erecting out-out switch; during the test the pins 8-9 of the plug connector for the BK-53PE erecting out-out switch must be short-circuited.

VIII. ILM-52 DIRECTIONAL GYRO, GET SERVICE TROUBLE, THEIR CAUSES AND REMEDIES

No.	Trouble	Cause	Remedy
1	2	3	4
Directional gyro (transmitter)			
1.	Instrument one-side error in azimuth exceeding specified value(directional gyro drift).	a) Inverter fails to stabilize frequency and maintain required voltage.	check voltage of aircraft electrical system. check length of brushes and condition of inverter commutator. Restart inverter from power source ensuring voltage of at least 120 V during starting. When inverter is connected to a power source of inadequate power, the starting contactor begins clicking and fails. If length of commutator brushes is lessened to 12.5 mm. and length of slip ring brushes is lessened to 9.5 mm., replace brushes.

When replacing brushes, fit them to commutator or slip rings by means of sand paper not coarser than No. "00" and polish them for 2 hours at idle speed. At normal operation, commutator and slip rings operating surfaces are brown in colour and do not require cleaning. If commutator and slip rings are burnt, wipe operating surface with clean cloth slightly moistened in gasoline. If carbon deposit still remains on operating surface of commutator and slip rings, clean them with sand paper not coarser than No. "00" (never use emery cloth for this purpose). After cleaning, wipe commutator and slip rings with clean cloth moistened in gasoline. Remove brush dust by air blast at a pressure up to 2 atm. Box located on inverter casing is allowed to be opened in service only when necessary to clean contacts of starting contactor. Do not adjust the other elements of inverter and box. In service never adjust inverter speed by changing gap between centrifugal regulator camshafts and do not clean contacts.

1	2	3	4	5
10. Gyro	Readjust gyro assembly balance by			
assembly is	correction potentiometer on control			
out of	panel. If indications of assembly			
balance.	drift change towards increase, turn			
	correction potentiometer on control			
	panel clockwise through as many divi-			
	sions as is the number of degrees by			
	which instrument readings have changed			
	for 30 min.			
	If indications of assembly drift change			
	towards decrease, readjust gyro			
	assembly balance in similar manner; in			
	this case turn correction potentiometer			
	counterclockwise.			
11. Horizont-	Check erecting cut-out switch for			
al erect-	proper shock-mounting. Erecting cut-out			
tion is off.	switch should be installed with letter			
	"E" up. Energize erecting cut-out switch			
	and check horizontal erection mechanism			
	alright for being energized; for this			
	purpose connect a.c. milliammeter in			
	strand of junction box terminal A 10.			

2. Turning of dial to the left and to the right at low speed is more asymmetrical than specified.	a) Increased friction in reduction gear. b) Change in A.C. voltage.	Remove seal from shutter at control panel plug connector. Through access hole in control panel casing adjust low synchronizing speed of dial rotation to the left (counter clockwise). To increase low speed of dial rotation to the left turn adjustment screw (through access hole) clockwise and to decrease speed turn adjustment screw counterclockwise. After adjustment check shutter and seal it.
3. High or low efficiency of latitude potentiometer does not correspond to specified values.	Change in A.C. voltage.	Remove seal from shutter at plug connector at control panel. Check efficiency of latitude potentiometer through access hole in control panel casing. To increase efficiency of latitude potentiometer turn adjustment screw clockwise.

1	2	3	4
2. Turning of dial to the left and to the right at low speed is more asymmetrical than specified.	a) Increased friction in reduction gear. b) Change in A.C. voltage.	Remove seal from shutter at control panel plug connector. Through access hole in control panel casing adjust low synchronizing speed of dial rotation to the left (counterclockwise). To increase low speed of dial rotation to the left turn adjustment screw (through access hole) clockwise and to decrease speed turn adjustment screw counterclockwise. After adjustment, close shutter and seal it.	
3. High or low efficiency of latitude potentiometer does not correspond to specified values.	Change in A.C. voltage.	Remove seal from shutter at plug connector on control panel casing. Efficiency of latitude potentiometer through access hole in control panel casing. To increase efficiency of latitude potentiometer turn adjustment screw clockwise.	

2	3	4
		through access hole a clockwise; to decrease efficiency turn adjustment screw counterclockwise. After adjustment close shutter and seal it.
<u>HUK-49 Indicator</u>		
1. Indicator dial rotates spontaneously.	Vibration from running engine.	Check vibration.
2. Readings of indicators differ from those of directional gyro (transmitter) by 180°.	Reversed polarity of directional gyro supply circuit.	Repair directional gyro supply circuit. Exchange S and P wires leading to directional gyro in junction box.
3. Considerable difference between indications of directional gyro (transmitter) and those of HUK-49 indicator.	Phase cables of directional gyro and HUK-49 indicator are reversed.	Exchange two phase cables of HUK-49 indicators.
4. When directional gyro rotates with in semicircle, indicator pointer remains at rest;	One of phase wires between directional gyro and HUK-49 indicator is broken.	Check plug connectors for secure wire attachment and repair broken wire.

when directional
gyro enters the
other semicircle,
indicator pointer
swing 180°.

- | | | |
|--|---|---|
| 5. Indicator pointer changes its position by jumping through large angles. | Intermittent contact in plug connectors or at junction box terminals. | Check plugs for being securely connected to receptacles of HXK-49 indicator and directional gyro (transmitter). |
|--|---|---|

IX. USING BIRECTIONAL GYRO

GROUND PREPARATION FOR FLIGHT

Navigational preparation for great-circle route flight includes:

1. Plotting the route on a chart.
2. Flight calculation;
3. Studying the route, traffic control aids and weather;
4. Planning the flight navigationally;
5. Determining the directional gyro check points en-route at a distance of one-hour or one-and-a half-hour flying from each other;
6. Computing the check points bearings.
7. Determining latitude correction points en-route.

The most convenient charts for plotting great-circle route flight are those of centre and polar stereographic projections with scale of 1:10000000; 1:20000000 or 1:30000000.

Great circles on such charts are plotted as straight lines.

The length of great-circle route flight can be measured on a centre projection chart by means of a scale ruler or computed from the following formula:

$$\cos S = \sin \varphi_1 \cdot \sin \varphi_2 + \cos \varphi_1 \cdot \cos \varphi_2 (\lambda_2 - \lambda_1)$$

where S - track distance in minutes of arc;

φ_1 and φ_2 - latitudes of departure and destination points;

λ_1 and λ_2 - longitudes of departure and destination points.

To determine the track distance in km. the S value must be multiplied by 1.85.

USING DIRECTIONAL GYRO IN FLIGHT

To use the directional gyro in flight, before taxiing out to the take-off position do as follows:

1. Energize the HF-70 inverter supplying power to the directional gyro (transmitter) and control panel and energize the MAT-1a inverter that supplies power to the erecting out-out switch. Set the switch on the control panel to the "ON" position.

2. Set the latitude potentiometer knob on the control panel to such a position that the scale division corresponding to the latitude of the aircraft present position is against the fixed triangle index under the "Latitude" inscription.

After take-off and arriving at the initial point of route (IPR) the navigator determines the drift angle (DA) required to compute the course from the (IPR).

When reaching the initial point of route, the navigator informs the pilot of the compass heading en-route from the IPR.

The IPR is passed with the most possible accuracy.

At the moment of passing the IPR the navigator establishes the required heading by the "Heading preset" knob on the control panel, matching the heading indication on the directional gyro dial with the triangle index.

In further flight the established heading is maintained by observing the dials of the directional gyro and MK-49 indicators.

When using the MK-52 directional gyro the instrument dial may be set for zero reading, and not for the preset heading. In this case the pilot and navigator need not watch the instrument indications and remember the established heading.

When making a turn to a new heading, set the directional gyro dial for the actual heading and then turn the aircraft until the new heading indication becomes again the triangle index of the directional gyro.

CORRECTING DIRECTIONAL GYRO INDICATIONS

The directional gyro is corrected in flight at check points according to navigational means available to the navigator (astronomical compass, land marks, magnetic compass and others).

The check points must determine the true course (TC), true drift angle (TDA) and heading (H) which are related as follows:

$$TC = H + TDA$$

Then the established course (EC) and lateral deviation (LD) are computed for the check points. Relations between lateral deviation, established course and true course are as follows:

$$EC = TC + LD$$

A correction to the directional gyro reading will be equal to the aircraft lateral deviation.

If the lateral deviation at a checkpoint is positive (+), then operating the heading preset knob on the control panel, turn the directional gyro dial counterclockwise for the lateral deviation value.

If the lateral deviation is negative (-), turn the dial clockwise.

When correcting the directional gyro indications by observing the readings of a magnetic compass or flux-gate compass, consider the time required for the card to settle (for example, for MKA-45 compass it is 4-10 min.), which occurs after the aircraft has taken off or made a continuous turn.

It is not always possible to correct the directional gyro by a magnetic compass, particularly in northern latitudes and areas with a small horizontal component of the earth magnetism vector.

The directional gyro readings can be checked in flight accurately by comparing them with those of the static compass both in straight flight and after turns.

Latitude correction must be introduced when latitude difference exceeds the latitude potentiometer scale division.

At extended operation of the directional gyro the gyro assembly may become unbalanced which will result in one-side drift. Therefore, the directional gyro must be checked before important flights and after every 20-30 operating hours.

In case of one-side drift balance the gyro assembly by turning the correction potentiometer on the control panel in the direction opposite to that of the directional gyro drift.

When the aircraft performs turns, the directional gyro cannot indicate true angles of turn at any moment due to a so-called "lateral error".

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This error is a reading error. It arises with the aircraft banking and disappears when the aircraft is levelled off. The "gimbal error" increases with the aircraft bank.

Relation between the maximum gimbal error value $\Delta\psi_{\text{max}}$ and aircraft bank (γ) is illustrated by the following Table:

γ	0	15°	30°	45°
$\Delta\psi_{\text{max}}$	0	1°	4°07'	9°42'

Due to the "gimbal error" the directional gyro indicates a non-constant rate of turn, while actually the aircraft is at a constant rate. This effect must be taken into account when using the instrument.

The directional gyro permits the aircraft to perform turns with a bank of 45° max.

When landing and taxiing the aircraft, the directional gyro must be energized.

1. PACKING, SHIPMENT AND STORAGE

Wrap the ITH-52 set units with craft paper and pack in special corrugated cardboard boxes. Put the certificate for the unit and plug connector into the box.

Place the cardboard boxes containing the units of the set in a wooden case having a water-proof layer or lined with bituminous or tar paper.

When put in the case, the boxes containing the units must be secured with straps that go as to prevent their shifting during

spaces between the boxes must be filled with dry wood shavings or pieces of paper.

On the outer side of the case the following inscriptions must be made with indelible paint:

- a) "Handle with care - Instruments"
- b) "Do not throw, do not turn over"
- c) "Fragile"
- d) "Unbox here"

Put a packing list in each case.

The cases containing the instruments must be stored in normal depot rooms on special shelves affording safety storage of the units.

Temperature in the depot room should be maintained within the range of -10 to +30°C at a relative air humidity of 20 to 60%.

The room where the instruments are stored should be free from vapours of acids, alkali, gasoline and other chemicals that are detrimental to the units.

Appendix 1.
 CONNECTIONS BETWEEN JUNCTION BOX AND OTHER UNITS OF THE SYSTEM
 GYRO UNIT

Directional gyro unit plug connector No.	Unit	Directional gyro unit plug connector No.	Directional gyro unit plug connector No.	Directional gyro unit plug connector No.
1	2	3	4	5
1	HT-70 Inverter two-pin plug connector.	1	1	1
	Five-pin plug connector	1	1	1
2	HAP-11 Inverter Five-pin plug connector			
3	Directional gyro unit 14-pin plug connector			

1	2	3	4
4	HK-55PE erecting cut-out switch 14-pin plug connector	1 2 3 4 5 6 7 8 9 10 11 12 13 14	- - - - - - - A10 - - - - -
5	Control panel 11-pin plug connector	A B C D E F G H I J K L	A9 A8 A7 A6 A5 A4 A3 A2 A1 - - -
6	ILAK-49 indicator 3-pin plug connector	1 2 3	A9 A8 A5
	3-pin plug connector	1 2 3	A8 A4 A3

Appendix II.

LIST OF TOOLS AND UNITS REQUESTED FOR THE 100th AIRBORNE AIRBORNE
COMBAT DIVISION

Nos.	Description	Unit	Remarks
1.	Test unit for testing		
	INR-52 directional gyro		
2.	SHN-46 test unit		
3.	Bracket for INR-52 directional gyro attachment on SHN-46 test unit		
4.	SHN-52 test unit		
5.	Spot tester		
6.	Concealer, instrument		
7.	Powerdriver, conventional		
8.	Breath, Rocket		
9.	Pliers		
10.	Cutting pliers		
11.	Weld torch		

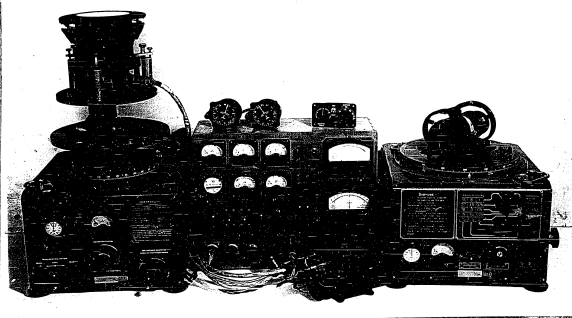


Fig. 5. HIR-52 Directional Antenna

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8D

AUTOPLOT Model: AIL-23A

DESCRIPTION

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14. "RECOVERY FROM BANK" button (KHII)	105

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I. PURPOSE

The AN-28M autopilot is designed for automatic control of transport aircraft.

The autopilot is employed to maintain the aircraft in straight-level flight position, to make coordinated turns at a bank of 30° max., to climb or glide at a pitch of 30° max., to return the aircraft to level flight position from any attitude at a bank and pitch of 30° max.

The autopilot is engaged without any preliminary preparation on any heading, at any position of the aircraft longitudinal and lateral axes (within $\pm 30^\circ$) relative to the natural horizon.

When the autopilot is engaged by a button, the heading and pitch will remain the same as they were at the moment of the autopilot engagement, if the aircraft was in the straight-level flight.

If before the autopilot engagement, the aircraft performed a coordinated turn, the aircraft will continue the coordinated turn at the same bank after the autopilot is engaged.

II. AUTOPILOT FUNCTIONAL DIAGRAM AND COMPLETING

By their function the aircraft-autopilot system elements are divided into:

1. Sensing
2. Amplifying
3. Servos
4. Control
5. Feed-back
6. Correcting
7. Power supply sources.

Shown in Fig.1. is a functional diagram illustrating the aircraft-autopilot system elements interaction.

If the aircraft deviates from the established position, the changes in roll, pitch and direction occur. These changes are picked-up by sensing elements and transmitted to the amplifiers and servo units.

A master vertical gyro operates as a sensing element measuring deviation angles relative the vertical.

A DMC-I flux-gate gyro compass is heading transmitter incorporated in the aircraft equipment.

Besides, a rate gyro is also a sensing element measuring an angular velocity of the parameters controlled. The altitude corrector is a sensing element responding to an altitude change.

Magnetic and electronic amplifiers serve as amplifying elements. PA-5B servo units power-operate the aircraft control surfaces.

The aircraft electrical system and HT-500H inverter are used as electric power sources.

The pilot's hand-grip and navigator's knob are control elements.

A feed-back is accomplished by feed-back transmitters.

Besides, the autopilot incorporates auxiliary correcting elements (not shown in Fig.1): erecting cut-out switch, vibrator, H.F. filter of angular velocity signal in the direction channel.

The AT-28M autopilot system (Fig.2) includes the following units:

- | | |
|---|-----|
| 1. Master vertical gyro (MTB-2) | - 1 |
| 2. Rate gyro (RVC-970B) | - 1 |
| 3. Altitude corrector (KB-11) | - 1 |
| 4. Control unit (AV-626) | - 1 |
| 5. Pilot's A.P. control hand-grip (PV-442B) | - 1 |
| 6. Navigator's turn control knob (PE-322A) | - 1 |

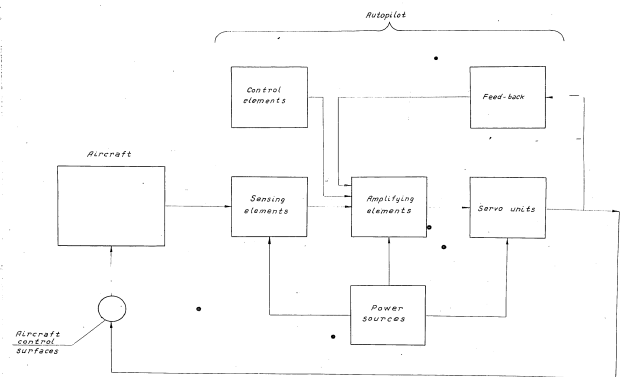


Fig. 1. Aircraft-Autopilot System Functional Diagram

- | | |
|-------------------------------------|-----|
| 7. Control panel (LV-822A) | - 1 |
| 8. Servo unit (PA-5B111) | - 3 |
| 9. Feed-back transmitter (ADU-600A) | - 3 |
| 10. Vibrator (B-847D) | - 1 |
| 11. "A.P.ON" button | - 1 |
| 12. "A.P.OFF" button | - 2 |
| 13. "RETURN TO LEVEL FLIGHT" button | - 2 |
| 14. "RECOVERY FROM BANK" button | - 1 |

III. AUTOPILOT EQUATIONS

The AM-28A is an autopilot with two-parameters control: angle and angular velocity with a rigid feed-back coupling.

When switching on the altitude corrector, the autopilot maintains the altitude according to signals proportional to an altitude change.

The autopilot theoretical equation for any of three channels at stabilization with the altitude corrector OFF will be:

$$\delta = i\gamma + \mu\dot{\gamma} \quad (1)$$

where: δ - control surface deflection angle (in deg.)

i - angle transmission ratio (control surface angle in deg. per a degree of aircraft deviation)

γ - aircraft deviation angle (in deg.)

μ - angular velocity transmission ratio (control surface angle in deg. per one-second angular velocity of the aircraft deviation)

$\dot{\gamma}$ - aircraft deviation angular velocity (deg. per second).

With the altitude corrector ON, the autopilot pitch channel equation is changed.

In this case the theoretical equation will be:

$$\delta_{el} = i_{el}\dot{V} + \mu_{el}\ddot{V} + K_{el}\Delta H$$

where:

δ_{el} - elevator angle

i_{el} - pitch transmission ratio

$\dot{V}$ - aircraft pitch angle

μ_{el} - rate-of-pitch transmission ratio

$\ddot{V}$ - aircraft rate-of-pitch

K_{EL} - altitude transmission ratio
(elevator deflection in deg. per one-meter change in altitude).

ΔH - altitude change.

At a turn the autopilot equation will be:

$$\delta_{AIL} = \delta_{AIL} (\gamma + \gamma_{\text{preset}}) + M_{AIL} \dot{\gamma}$$

$$\delta_{AIL} = \delta_{AIL} V + M \dot{V} + (K_{EL} \gamma_{\text{preset}})$$

$$\delta_{RUD} = K_{\phi} \cdot \psi$$

where ψ - aircraft rate-of-yaw

K_{ϕ} - transmission function of filter in direction channel.

IV. AUTOPILOT PRINCIPLE OF OPERATION AND SCHEMATIC DIAGRAM

The aircraft-autopilot system operation for each channel is as follows:

When the aircraft deviates away from the established position, signals are summed up, amplified, the aircraft deviation angle and angular velocity, fed to a servo unit and move its valve for a value corresponding to a total output signal.

It results in the servo unit rod movement at a speed proportional to the valve travel. With the servo unit rod moving a feed-back signal starts increasing; the signal is fed to the amplifier input and acts in reverse phase with gyro units input signal.

It results in the servo unit rod motion speed decreasing. When the feed-back signal attains a value equal to the total input signal, the servo unit rod stops and a control surface is deflected at a value proportional to the total input signal.

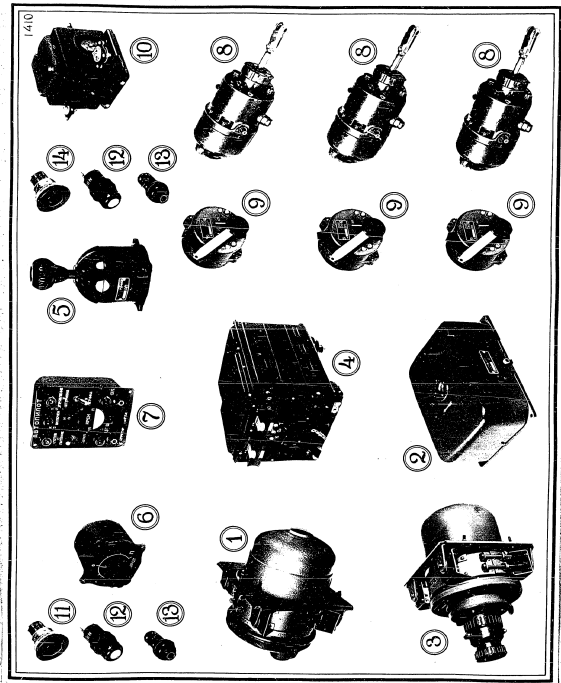


Fig. 2. AN-200 Autopilot Elements

The control surface deflection brings the aircraft back to the original position.

The autopilot "1" and "M" parameters characterize the aircraft return to the pre-set position.

The signals, proportional to the aircraft deviation angle, stabilize the aircraft about C.G. and the signals, proportional to angular velocity, damp oscillations.

The aircraft heading and altitude path is controlled by the A.P. control grip and knob.

The heading control is achieved by a coordinated turn at a bank of 10° to 30° .

With the autopilot disengaged, the servo units rods move freely and do not interfere with the aircraft manual control system.

Fig. 3 and 4 illustrate the aircraft-autopilot system block diagram and schematic wiring diagram.

The autopilot operation may be divided into the following stages:

1. Switching the autopilot power supply ON.
2. Synchronization mode (automatic preparation of autopilot for engagement).
3. Engaging the autopilot.
4. Level flight.
5. Controlled flight.
6. Operating the autopilot by "RETURN TO LEVEL FLIGHT" button.
7. Disengaging the autopilot.

In Fig. 3 the contacts are shown in the synchronization mode of operation.

At all the aircraft deviations, the signals, generated by the master vertical gyro and feed-back transmitters, enter the magnetic and electronic amplifiers and then the synchronizing mechanism for the roll and pitch channels.

From the synchronizing mechanism, the signal, fed into the magnetic

amplifier compensates all the magnetic amplifier input signals. In the directional channel, the signal from the flux-gate gyro compass is supplied to the synchronizing mechanism. The synchronizing mechanism senses the signal to the magnetic and electronic amplifiers. The electronic amplifier returns the signal back to the synchronizing mechanism to compensate the flux-gate gyro compass signal.

In a straight flight the contacts (1-8) are actuated. Therefore, with the roll and pitch channels deviations, the signals from the master vertical gyro, rate gyro and flux-gate gyro compass are supplied to the magnetic amplifier.

The rate gyro signal preliminarily passes through a phase-sensing rectifier, and the flux-gate gyro compass signal - through the synchronizing mechanism (through its potentiometer).

The magnetic amplifier sends the signals in sequence to the electronic amplifier, vibrator, detector and servo unit. The servo unit moves a control surface and makes the feed-back transmitter create a signal which is fed to the magnetic amplifier input and compensates all the input signals to operate the control surface in an amount proportional to the input signals.

When the aircraft is controlled by the pilot's left control hand grip, contacts 9, 10 and 11 are actuated. When the pilot moves the hand-grip in the pitch direction, a signal is sent to the pitch synchronizing mechanism and then through the amplifier, vibrator and detector to the servo unit which operates the elevator in response to the pilot's control.

When the pilot moves the hand-grip in bank direction, a signal is sent to the bank synchronizing mechanism which in its turn sends a signal to the bank magnetic amplifier and to the pitch magnetic amplifier and the aircraft control surfaces are operated.

A signal is fed to the pitch channel to compensate an altitude loss when turning. The contact (10) is actuated to connect the heading synchronizing mechanism to the magnetic amplifier with an internal feed-back.

This results in compensating (bringing to zero) the signals generated by the flux-gate gyro compass at a turn.

The contact (11) is actuated and connects additionally to the signal a filter which is employed for damping the aircraft motion at a turn without slipping or skidding in a properly banked turn.

The pilot may transfer the control to the navigator. In this case, the contacts (4 and 12) are actuated and disengage the pilot's A.P. control hand-grip and engage the navigator's turn control knob. The navigator can only control the aircraft bank.

When the navigator turns the knob, a signal is sent to the bank magnetic amplifier, and a portion of the signal is sent to the pitch magnetic amplifier to compensate an altitude loss when turning.

The pilot can actuate the contact (13) at any flight condition.

Shown in the diagram is an erecting cut-out switch de-energizing the lateral erection of the master vertical gyro at a turn.

I. ENERGIZING THE AUTOPILOT

The autopilot is power supplied from the 27-volt aircraft electrical system. The negative wire is connected to the pin (45) of the control unit (see Fig.4) and then through the autopilot circuit (see the diagram points with sign "-").

The positive wire is connected to the "POWER" switch of the control panel and to the switching relay of the autopilot three-phase power.

The autopilot is energized by the switch (8₁). In this case,

"Plus" is conducted to the relay (P14) and to the autopilot system (see the diagram points with sign "+").

If at a sign "+" or "-" is figure 300 it means that connected to this point is "plus" or "minus" of 300 volts.

The relay (P14) being actuated and its contact (P14-2) energizes the three-phase power relay.

The three-phase 36 V, 400 c.p.s. power energizes the control unit (pins A1, A2, A3 and all the points marked II, I and III), rate gyro (pins B1, B2, B3), master vertical gyro (pins E3, E4, E5), altitude corrector (pins Bk3, Bk4, Bk5).

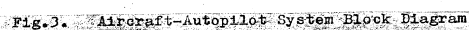
The alternating current fed to the control unit energizes the bimetallic relay (H4) and rectifying bridge (M) which supplies D.C. to the relay (P12).

The normally-closed contact (P12-1) of this relay will be open until the bimetallic relay opens. The bimetallic relay opens in 35-450 sec. after the relay is energized, (time required for the gyros to gain speed and for warming-up the electronic valves).

As soon as the bimetallic relay opens, the relay (P12) is de-energized and the contact (P12-1) closes and sends "plus" to the master vertical gyro light (L3) of the control panel and through the button (ON) to the "RETURN TO LEVEL FLIGHT" and "A.P. OFF" button and, through the contact (P3-4) to the "READY" light (L1). With the light (L1) on it indicates that the autopilot is ready for engagement.

2. SYNCHRONIZATION MODE

After the autopilot is energized with 27-volt, and 36-volt, 400 c.p.s. A.C., the synchronizing mechanisms automatically compensate the input signals.



All the signals picked up by the bank, and pitch potentiometers, the master vertical gyro angle transmitters, IVM-1 gyro flux-gate compass and feed-back transmitters are amplified by the magnetic and electronic amplifiers and sent to the synchronizing mechanism motors through the contacts (P1-2, P1-4 and P1-6).

The voltages picked up by the mechanism potentiometers are supplied to the magnetic amplifiers windings and compensate all their input signals.

Take, for example, the compensation of the master vertical gyro angle transmitter signal by the mechanism.

Assume that the master vertical gyro is tilted through some angle in pitch. In this case the master vertical gyro angle potentiometer sends a signal to the magnetic amplifier. This signal will be amplified by the magnetic and electronic amplifiers and will be fed to the pitch synchronizing mechanism motor windings. The motor starts rotating. The motor stops rotating when the synchronizing mechanism potentiometer signal, compensating the M.V.G. signal, is received by the magnetic amplifier.

The synchronizing mechanism wiper will be deflected through some angle. Thus, the M.V.G. angle corresponds to the deflection angle of the mechanism potentiometer wiper.

The AP-26R autopilot is designed so that with the M.V.G. tilting through 36° , the potentiometer wiper deflects 40° . The synchronizing mechanism is fitted with a stop at this angle and with the further tilting of the M.V.G., the mechanism cannot compensate the input signal. The non-compensated signal is sent to the electronic amplifier.

The voltage of the 2-3 stage of the electronic amplifier through a capacitor (C3), resistor (R22) and vibrator transformer winding is supplied to the detectors grids in which output circuit is the relay (P27) connected in series with the control windings of the servo of polarized relays (IP1, IP2 and IP3).

The relay (P27) is actuated and connects the relay (P13) which by its contact (P13-1) de-energizes the autopilot "ON" button and the "BRAKE" light (L1); the latter is illuminated only when the synchronization takes place.

Thus, the bank and pitch channels cannot energize the autopilot with the aircraft banked or pitched through an angle exceeding 30°.

In the direction channel the synchronization with the compass is accomplished by the three-wire potentiometers system shown in Fig. 5.

In the TWM-I compass potentiometer, on its right and left halves, the potential uniformly increases from the point contacted by the potentiometer wiper "a" to the point contacted by the potentiometer wiper "b". The potential distribution pattern on the synchronizing mechanism potentiometer is due to the equality of the potential points of the two potentiometers (TWM-I compass and synchronizing mechanism) connected by wires (1-1, 2-2 and 3-3).

Therefore, the voltage (U_1) between the synchronizing mechanism potentiometer wipers will be equal to zero in the position (1), i.e. when these wipers contact the diametrically opposite points with equal potentials (V_1).

Assume that for some moment the potentiometer wipers position and potential distribution (shaded) is as shown in Fig. 5a, i.e. there is a unsynchronizing angle (α).

In this case some voltage is fed from the synchronizing mechanism wipers to the magnetic amplifier.

This voltage is amplified by the magnetic and electronic amplifiers and is supplied to the synchronizing mechanism motor windings.

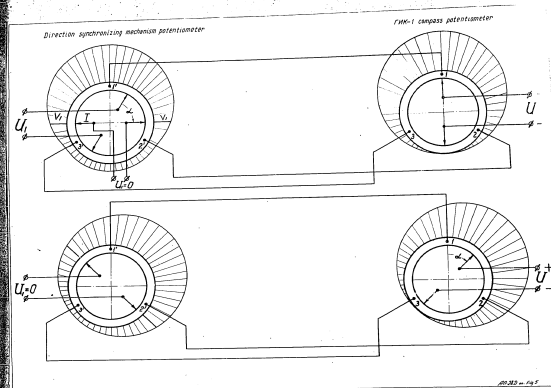


Fig. 5. Three-wire Potentiometers System

The $IM-0.5$ motor and, therefore, the potentiometer wipers will rotate. The rotation is stopped when the voltage, picked-up by the synchronizing mechanism potentiometer wipers, will be equal to zero.

In this case the system will be in the synchronized position. Now, if the $IM-1$ compass wipers are turned through an angle (α_1), the three-wire system potentials will be re-distributed, the unsynchronization voltage appears which will be amplified and fed to the synchronizing mechanism motor windings. The motor will rotate until the unsynchronizing voltage is compensated. In this case the synchronizing mechanism wipers will occupy a new synchronized position (see Fig. 5b).

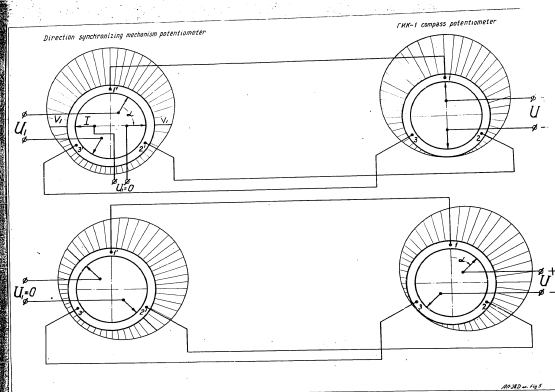


Fig. 5. Three-wire Potentiometers System

The MM-0.5 motor and, therefore, the potentiometer wipers will rotate. The rotation is stopped when the voltage, picked-up by the synchronizing mechanism potentiometer wipers, will be equal to zero.

In this case the system will be in the synchronized position. Now, if the MM-1 compass wipers are turned through an angle (α_1), the three-wire system potentials will be re-distributed, the unsynchronization voltage appears which will be amplified and fed to the synchronizing mechanism motor-windings. The motor will rotate until the unsynchronizing voltage is compensated. In this case the synchronizing mechanism wipers will occupy a new synchronized position (see Fig. 5b).

Thus a definite position of the TML-I compass potentiometer corresponds to a definite synchronized position of the synchronizing mechanism wipers. Besides, the direction synchronizing mechanism, as well as the pitch and bank mechanisms, compensate the signals of the feed-back transmitter and the signals of the magnetic amplifier centering.

In all these cases, if for some reasons the servo units polarized relay control windings are energized, the autopilot cannot be engaged, i.e. the relay (P27) will be actuated and de-energize the "ON" button as described above.

The autopilot cannot be engaged if the autopilot circuit receives the M.V.G. knock-out signal; this signal is observed on the M.V.G. indicator located on the control panel. In this case, the relay (P10) is actuated and by its contact (P10-1) de-energizes (+27 V) the autopilot "ON" button and the "READY" light (JL) and "M.V.G." light (JL3) located on the control panel; the relay (P10) is interlocked by its contact (P10-2).

To erect the M.V.G. press the "CAGE" button on the control panel. The M.V.G. quick erection is outlined in the M.V.G. description.

The relay (P27) input signal actuating zone is adjusted by selection of a resistor (R22). The resistor (R22) is chosen so that the relay (P27) would be actuated at the M.V.G. signal corresponding to 1.5° bank.

The rate of the synchronizing mechanisms actuation depends on the electronic amplifier output signal and is adjusted by the amplifier internal negative feed-back circuit consisting of capacitors (C₁ and C₂) and a resistor (R14) which change the amplifier amplification factor. With the resistance (R14) increasing to infinity there is no a feed back and the amplification factor is maximum. With the resistor (R14) short-circuited, the feed back decreases the amplifier amplification factor.

ation factor to minimum. The resistor (R14) is chosen so that the synchronizing mechanism would not enter the self-oscillation condition and the signal actuation rate would be sufficient.

Thus, the autopilot is considered ready for operation if the following conditions are obtained:

1. The bimetallic relay is actuated which provides a time delay required for warming-up the valves, spinning the gyro motors and erecting the M.V.G. axis in vertical position;

2. Output voltages of the bank, pitch and direction amplifiers should be about zero.

3. No M.V.G. knocking-off signal is permitted.

4. The aircraft bank and pitch angles should not exceed 30°.

The autopilot is ready for engagement when the "READY" light (J1) and "M.V.G." light (J3) on the control panel are ON.

3. ENGAGING THE AUTOPILOT

The autopilot is engaged by pressing the autopilot "ON" button on the pilot's A.P. control hand-grip or the A.P. "ON" button in the navigator's cabin.

In this case the relay (P1, P2, P3, P15, P16, P20 and P32) are actuated and interlocked.

The relay contacts (see Section VI) perform the following:

1. They switch off the "READY" light (J1) and switch on the "ON" light (J2) on the control panel.

2. They cut out the amplifiers output to the synchronizing mechanism's motor control windings.

3. They switch the electronic amplifier feed back circuit which increases its amplification factor and short circuit the electronic amplifier output line resistor; this resistor limits the actuating

zone of the polarized relay (P27) in the synchronizing mode.

4. They switch on the feed back circuit of the whole amplifying system.

5. They connect the angular velocity induction transmitters signal windings to the autopilot system.

6. They disconnect the relay (P27) and connect the limiting resistor (R34) to the electronic detector output circuit.

7. They connect the pilot's A.P. control hand-grip potentiometers to the control windings of the pitch and bank synchronizing mechanisms motors.

8. They actuate the solenoid valves of the servo units.

The solenoid valves disconnect the operating chambers of the servo units.

The latter begin operating in accordance with the autopilot signals.

9. They switch on the vibrators.

10. They switch off the M.V.G. cage circuit with the autopilot engaged.

11. They decrease the YMK-I compass signal steepness to a value required for normal stabilization in the direction channel.

After the pilot has engaged the autopilot, the aircraft continues flying under the autopilot control in the same condition which was at the moment the autopilot was engaged.

A fuse (F₁₂) for a nominal current of 2A is provided to check the serviceability of the control unit power transformer.

The fuse is blown out with the transformer winding turns short circuited. During the normal operation of the autopilot the relay (P12) winding is shunted by the fuse.

The blown-out fuse breaks the shunt circuit and the relay (P12)

becomes connected in series with the primary low-resistance winding of the transformer. In this case the relay is actuated and by the normally-closed contact (P12-1) disconnects the autopilot transferring it to the synchronizing mode.

4. LEVEL FLIGHT

In a level flight at a turbulence deviating the aircraft from an established condition, the D.C. signals from a corresponding angle transmitter (M.V.G. or FTK-I compass) and A.C. signals from a rate gyro are rectified in phase-sensitive rectifiers and sent to the control windings of the magnetic amplifier.

The summed-up and amplified signals are fed to the electronic amplifier input. The electronic amplifier consists of two stages based on a 6X4 valve. The amplified signals are supplied to the vibrator and detector grids.

The detector is based on a 6X4 valve and its plate circuits incorporate the control windings of the servo unit polarized relay.

The polarized relay armature moves the valve for a value proportional to an input signal.

The hydraulic fluid under a pressure enters the servo unit and moves the rod at a speed proportional to the amount of the valve movement, i.e. to a total control signal.

With the servo unit rod moving, the feed-back transmitter signal is supplied to the magnetic amplifier to compensate the control signal.

When the feed-back transmitter signal is equal to the control signal, the servo unit valve returns to the initial position, the servo unit rod stops moving and a control surface is moved for an amount proportional to the control signal.

Under the action of the deflected control surface the aircraft returns to the initial position.

Simultaneously the negative feed-back signal from the detector output is fed to the magnetic amplifier to regulate the gain factor, of the amplification system which consists of a magnetic amplifier, electronic amplifier and detector.

The gain factor is chosen separately for the synchronizing mode (the electronic amplifier circuit feed-back is on and the amplification system feed-back is off with the relays (P4 and P16) in the bank and pitch channels and the relays (P1 and P15) in the direction channel) disconnected and for the stabilization mode (the electronic amplifier circuit feed-back is off and the amplification system feed-back is on with the relays (P1, P15 and P16) connected).

5. CONTROLLED FLIGHT

With the autopilot engaged in flight, sometimes the pilot needs to change altitude or perform a turn.

For this purpose the A.P. control hand-grip is used. The hand-grip controls the rate of a maneuver performed. It means that with the control hand-grip in a certain position, a definite angular velocity of the aircraft movement is obtained, i.e. the more the A.P. control hand-grip is deflected the more the angular velocity of the aircraft movement appears, and vice-versa.

The A.P. control hand-grip system is supplied with A.C. through the contacts (P7-3 and P7-5); the alternating current is supplied to the hand-grip potentiometers wipers.

The potentiometers (H24) regulate the speed of the synchronizing mechanism rotation. The purpose of the contacts (P7-3, P7-5) is outlined in paragraph IV, 6 and VI.

The control hand-grip potentiometers have an insulated section preventing a signal to be supplied to the synchronizing mechanism windings with the hand-grip in zero position.

Connected in the centre part of the hand-grip potentiometers are resistors (R45) decreasing the unsensitivity zone; the resistors (R45) at small angles of the hand-grip deflection increase the difference between the potentiometer arms resistances by the value of the resistance (R45). Therefore there is an increase in the current difference, to which the synchronizing mechanism motor responds.

With no resistors (R45), at small angles of the hand-grip deflection a small current difference would appear (the resistances of the potentiometer arms differ from each other by a small value) and the synchronizing mechanism motor would not respond to it, i.e. the motor remains at rest.

c) Pitch Control from the A.P. Control Hand-Grip

Control in the vertical plane is performed as follows:

With the hand-grip deflected for pitch, the potentiometer signal is fed to the control windings of the pitch synchronizing mechanism motor. The signal makes the motor rotate in the corresponding direction at a speed proportional to a current in the control windings. The motor through a reduction gear rotates the potentiometer from which a signal is supplied to the magnetic amplifier. This deflects the elevator and thus a manoeuvre of the aircraft is performed. The signal from the M.V.G. pitch angle transmitter compensates the increasing signal of the synchronizing potentiometer. The pitch angle transmitter signal should have a rate equal to that of the potentiometer. A differential signal appears which additionally

and, thus, changes a rate of the aircraft deviation.

Therefore the rate of pitch corresponds to the angle of the hand-grip deflection.

When the aircraft reaches a required angle of pitch, the hand-grip returns to neutral position, but the angle of pitch still continues changing as due to the action of a deflected elevator the aircraft should move through some angle in order that the M.V.C. signal brings the amount of the elevator deflection to zero.

To compensate this additional angle of the aircraft deviation, simultaneously with the signal fed to the synchronizing mechanism, the control hand-grip sends an "ADVANCE" signal to the magnetic amplifier (terminals 8,10) through the phase-sensitive rectifier.

This signal acts as follows:

with the hand-grip deflecting a constant signal, proportional to the angle of the hand-grip deflection, is supplied to the magnetic amplifier; this signal deflects the elevator in the desired direction and when the hand-grip returns to neutral position the signal is cut out, i.e. the elevator deflects tending to stop change in pitch.

b) Altitude Stabilization

The altitude stabilization is performed by the altitude corrector actuated by the "KH" (Altitude corrector) button on the control panel. Simultaneously the altitude corrector light (AL) appears indicating that the altitude corrector is on. With a change in the flight altitude, the altitude corrector potentiometer wiper moves from zero position and the magnetic amplifier is energized by the voltage proportional to a change in altitude tending to stabilize the aircraft altitude position. The aircraft can be stabilized in altitude under any flight condition except for descent or climbing. In this case it is not recommended to switch on the altitude corrector as a signal from

the M.V.C. may exceed the maximum value of the signal from the altitude corrector potentiometer and, therefore, its value will be insufficient to bring the aircraft axis to a position required for level flight. So it is impossible to switch on the altitude corrector with the hand-grip deflected for pitching as it is automatically switched off with the hand-grip deflected. In this case a voltage from the hand-grip contacts is supplied to the relay (P11 or P21).

The relay is actuated and the contacts (p11-1 or P21-1) de-energize the relay (P22) which in its turn de-energizes the altitude corrector. The altitude corrector is cut out and the light (L3) on the control panel disappears.

c. Coordinated Turn Controlled by the Pilot's Hand-Grip

If the pilot wants to perform a turn, he, deflecting the hand-grip for bank, makes the aircraft perform a coordinated turn at an angular velocity depending on the angle of bank. The angle of bank is obtained in the system as follows:

with the hand-grip deflected through an angle, a signal from the hand-grip potentiometer is fed to the control windings of the bank synchronizing mechanism motor which, rotating, moves the potentiometer wiper at an angular velocity determined by the angle of the hand-grip deflection.

The signal from the synchronizing mechanism potentiometer is supplied to the magnetic amplifier; as a result of this such a rate of roll is obtained which is proportional to the angle of the hand-grip deflection.

When the aircraft reaches a required angle of bank the hand-grip is released.

The synchronizing mechanism stops rotating but the angle of

bank still continues changing as due to the action of the deflected control surface the aircraft should move through some angle more.

To compensate this angle, as well as at a pitch control, an "ADVANCE" signal is sent whose action was described above. On entering a bank, the aircraft will turn under the action of a side force.

In this case, signals appear on the sensing elements, gyro flux-gate compass and rate gyro.

The YMK-I compass signal is cut off the servo unit amplifier and is transferred to synchronization with the direction synchronizing mechanism potentiometer.

Transfer to synchronization and self-synchronization is obtained as follows: with the hand-grip deflected for bank, the voltage from the bank synchronizing mechanism contacts is supplied to the relay (P16 or P17 depending on a turn direction). The contacts (P16-2 or P17-2) close the relay (P6) which by its contacts (P6-1 and P6-4) connects the direction synchronizing mechanism wipers to the turn magnetic amplifier (with the internal feed-back).

A signal appearing during the turn generates an unbalanced voltage across the direction synchronizing mechanism potentiometer. This voltage will be amplified by the magnetic amplifier and be supplied to the synchronizing mechanism motor winding. The rotating motor will synchronize the system. A signal from the rate gyro is fed through the contact (P6-3) to the filter consisting of the capacitors (C12, C13) and resistors (R49-3 and R 50-3). The filter locks out the rate gyro signal of constant angular velocity relative to the aircraft vertical axis during a turn (the capacitors prevent D.C. flow).

Thus, during a turn, the rudder remains in neutral position and the aircraft makes a coordinated turn.

If at a turn, due to some reasons, the aircraft starts oscillating,

the filter capacitors will be recharged and the magnetic amplifier will receive signals shaking the rudder to damp the aircraft oscillation.

To compensate an altitude loss during a turn a portion of a signal from the bank synchronizing mechanism through the contacts (P16-1 and P17-1) is supplied to the pitch magnetic amplifier. This signal irrespective of a turn direction will deflect the elevator (upward) to compensate the altitude loss. The altitude loss compensating signal accurately compensates the altitude loss in one flight condition. The complete compensation of the altitude loss under other flight conditions is not important, as it will not create slipping. To stabilize the altitude, the pilot may switch on the altitude corrector.

d) Aircraft Control by the Navigator's Turn Control Knob

When the pilot sets the "B2" switch to the "NAVIGATOR" position, the voltage is supplied to the light (J4) on the control panel and to the relays (P19 and P29). The illuminated light (J4) indicates that the autopilot control is transferred to the navigator and he can control the A.P. by the turn control knob. The navigator cannot control the flight altitude.

An angle of the knob turn corresponds to a definite bank angle of the aircraft. The relays (P19 and P29) are actuated and by their contacts de-energize the pilot's hand-grip potentiometer, return the aircraft to level flight by applying voltage to the bank synchronizing mechanism, contacts and electric motor.

The return to level flight is necessary to obtain a zero bank of the aircraft, with the navigator's control knob in zero position, and to prevent an angle of bank exceeding 30° ; the navigator operating the knob can make a 20° bank which being added to the initial angle of bank, if there was no returning to level flight, would result in an

angle of bank exceeding the permissible amount. As soon as the aircraft is returned to level flight position the voltage through the contact in the middle insulated section of the segments assembly and the contact (P19-2) is fed to the relay (P28) which in its turn, supplies voltage to the relays (P23 and P24) and to the navigator's knob potentiometer.

The relay contacts (P23-1 and P23-2) select the altitude compensation signal for power supply from the navigator's knob.

The contact (P24-2) locks "plus" at the navigator's switch.

After the aircraft has recovered from a bank, the navigator can control the aircraft by the knob. With the knob turned, signals are supplied to the bank and pitch magnetic amplifiers. The signal from the knob is amplified by the bank magnetic amplifier and is fed to the servo unit deflecting the ailerons.

The deflected ailerons make the aircraft bank.

At a bank a signal from the M.V.G. bank potentiometer compensates the knob signal and sets the control surface in neutral position and the aircraft becomes deviated for some angle. Therefore, an angle of the knob turn corresponds to that of the aircraft deviation.

The signal fed to the pitch magnetic amplifier moves the elevator up and prevents an altitude loss during a turn.

Simultaneously with these signals, the voltage, from the navigator's knob contacts, is sent to the relay (P25 or P26) depending on the direction of a turn. The contacts (P16-2 or P17-2) supply voltage to the relay (P6) which synchronizes the direction channel (see the coordinated turn controlled by the pilot's hand-grip).

Besides, the autopilot has a provision for interlocking the control transfer system if the navigator's knob is deflected when the control is transferred to the navigator.

With the knob turned, the voltage from the knob contacts (as

mentioned above) is supplied to the relay (P25 or P26).

The contact (P25-1 or P26-1) de-energizes the "NAVIGATOR" switch and prevents the control transfer to the navigator.

During a turn controlled by the navigator's knob, the pilot can change the altitude of flight by operating the hand-grip or stabilize the flight altitude by pressing the altitude corrector button on the control panel.

To transfer the side motion control to the pilot, he must set the selector switch in the "PILOT" position. In this case the navigator's control system is switched off.

6. "RETURN TO LEVEL FLIGHT" BUTTON OPERATION

To level the aircraft from bank and pitch within 30° , for which the autopilot is preset, press the "RETURN TO LEVEL FLIGHT" button located at the pilot's and navigator's stations.

In this case the relays (P7, P8 and P30) are actuated and interlocked by the contact (P7-2). The relays contacts (P7-3, P7-5, P30-1 and P30-2) supply voltage to the synchronizing mechanisms motors through the segments assemblies. The motors start rotating. When the motors are rotating their potentiometers send signals to the magnetic amplifiers; these signals deflect the control surfaces to decrease the bank and pitch of the aircraft.

The aircraft motion to the level position will increase the M.V.C. signal which stops the control surface movement.

The angular velocity of the aircraft rotation is established; this angular velocity is determined by the angular velocity of the synchronizing mechanism rotation (similar to the control from the pilot's hand-grip).

The synchronizing mechanisms motors stop rotating when the segments assembly wipers reach the insulated section.

In this case, the voltage from the potentiometers wipers to the magnetic amplifiers will be approximately equal to zero and, thus, the aircraft will occupy approximately neutral position. The amount of the residual angles of bank and pitch is regulated by the magnetic amplifiers centering potentiometers (HI-1 and HI-2) located on the control panel.

In the middle part of the insulated section of the segments assembly is the contact used for automatic actuation of the altitude corrector after the aircraft axes are set in level position by the "RETURN TO LEVEL FLIGHT" button.

When the pitch synchronizing mechanism segments assembly wiper reaches this contact, the voltage is applied to the altitude corrector, relay (P22) and light (L5) on the control panel through the contact (P7-6). The contact (P22-2) locks the voltage applied to the altitude corrector. The illuminated light (L5) indicates that the altitude corrector is on. The contacts (P7-3, P7-5 and P8-1) de-energize the pilot's hand-grip and the navigator's turn control knob. This prevents using the hand-grip and knob during the return-to-level-flight mode.

If before switching on the "RETURN TO LEVEL FLIGHT" button the autopilot is disengaged, i.e. the autopilot operates in the synchronizing mode, then with the button pressed the relays group (P1, P2, P3, P15, P18, P20) are actuated by the contact P7-1 and the contact (P7-4) shunts the relay (P27). It prevents the relay (P27) actuation due to delay in actuation of the return-to-level-flight relay and the relay group operated by the "RETURN TO LEVEL FLIGHT" button in the synchronizing mode.

To transfer the autopilot from the return-to-level-flight mode to the normal mode of operation, press the A.P. "ON" button.

In this case the interlocking circuit of the relays (P7, P8, P20) is open. The relays (P7, P8 and P20) are de-energized and the contacts (P7-3, P7-5) energize the hand-grip bank and pitch potentiometers and together with the contacts (P30-1 and P30-2) de-energize the motors through the segments assemblies. The autopilot is switched over to the normal operation in the stabilizing or control mode.

Located on the pilot's instrument panel is the "RECOVERY FROM BANK" button, by means of which the pilot, after a turn, can more accurately bring the aircraft to level flight position without changing the angle of pitch.

The aircraft returns to level flight position only with the "RECOVERY FROM BANK" button pressed.

To recover from bank to level position the relays (P19 and P29) are used to transfer the control to the navigator. The operation of these relays is described in the section "Control from the Navigator's Knob".

With the "RECOVERY FROM BANK" button pressed, the light (L4) on the control panel indicating that the control is transferred to the navigator should not be illuminated.

7. DISENGAGING THE AUTOPILOT

The autopilot is disengaged from the control surfaces by pressing the autopilot "OFF" button. In this case the relays (P1, P2, P3, P32, P15, P18, P20) interlocking circuit is open (these relays engage the autopilot) and simultaneously the servo units solenoid valves are de-energized; the servo unit chambers become communicated and the autopilot does not interfere with the manual control of the aircraft.

The autopilot is switched over to the synchronizing model. The autopilot can be disengaged by the "TOWER" switch (B1) on the control panel.

In this case the whole autopilot system and the servo units solenoid valves are de-energized.

V. *AN-24* AUTOPILOT MAIN TECHNICAL DATA

1. Electric power supply sources:
 - a) direct current - aircraft electrical system, $27V \pm 10\%$.
 - b) alternating current - aircraft electrical system, three-phase, $56 \pm 2 V, 400 \pm 5 c.p.s.$
2. Hydraulic power sources:
 - a) hydraulic system, *AMH-30* fluid, 60-80 atm.
3. Power drawn:
 - a) 90 w. D.C.
 - b) 24 A.C. in each phase.
4. Maximum hydraulic fluid consumption - 10.5 litres/min.
5. Time required for the autopilot to be engaged not more than 10 sec.
6. Heading accuracy $\pm 1^\circ$
7. Pitch accuracy $\pm 0.5^\circ$
8. Bank accuracy $\pm 0.5^\circ$
9. Altitude accuracy $\pm 20 m.$
10. Bank and pitch angles range permitting to engage the autopilot $\pm 30^\circ$
11. Angle of bank during a turn up to $\pm 30^\circ$
12. Pitch control within $\pm 30^\circ$
13. Maximum forces developed by *PA-5B01* servo units $140 \pm 15 kg.$
14. Forces required to override the autopilot:
 - a) for control wheel 10-20 kg.

- b) for control column 30-45 kg.
 c) for rudder pedals 30-65 kg.
 15. Operating temperature range ... -50°C to -60°C
 16. Ceiling up to 18,000 m.
 17. Autopilot weight 47 kg.
 18. Guaranteed service life 500 hours

19. AN-28H AUTOPILOT RATIOS:

Bank	Angle	$\dot{\alpha}_{\text{ail.}} = 1.4 \pm 0.15$	$\frac{\text{ail. deg.}}{\text{aircraft deg.}}$
	Angular velocity	$\dot{\alpha}_{\text{ail.}} = 0.75 \pm 0.1$	$\frac{\text{ail. deg.}}{\text{deg./sec. aircraft}}$
Pitch	Angle	$\dot{\alpha}_{\text{elev.}} = 1.23 \pm 0.16$	$\frac{\text{elev. deg.}}{\text{aircraft deg.}}$
	Angular velocity	$\dot{\alpha}_{\text{elev.}} = 0.4 \pm 0.05$	$\frac{\text{elev. deg.}}{\text{deg./sec. aircraft}}$
Direction	Angle	$\dot{\alpha}_{\text{rud.}} = 1.25 \pm 0.16$	$\frac{\text{rud. deg.}}{\text{aircraft deg.}}$
	Angular velocity	$\dot{\alpha}_{\text{rud.}} = 1.1 \pm 0.15$	$\frac{\text{rud. deg.}}{\text{deg./sec. aircraft}}$
Altitude	ΔH	$K_{\text{elev.}} = 0.06 \pm 0.007$	$\frac{\text{Elev. deg.}}{\text{mm. H}_2\text{O}}$

20. Maximum control speed from the pilot's hand-grip for bank 2 ± 0.5 deg./sec.
 for pitch 1.75 ± 0.4 deg./sec.
 21. Return-to-level-flight speed
 for bank 4 ± 1 deg./sec.
 for pitch 1.2 ± 0.3 deg./sec.

VI. DESCRIPTION AND PURPOSE OF RELAYS INCORPORATED IN THE AUTOPILOT SYSTEM

Rel. No.	Type	Actuating signal	Location	Contacts group purpose
1	2	3	4	5
P1	PC13-10	Actuated by A-F "ON" button	Control unit	P1-1. Feed-back circuit of bank channel electronic amplifier switching. P1-2. Bank synchronizing mechanism motor off. P1-3. Feed-back circuit of pitch channel electronic amplifier switching. P1-4. Pitch synchronizing mechanism motor off. P1-5. Feed-back circuit of direction channel electro- nic amplifier switching. P1-6. Direction channel synchronizing mechanism motor off.
P2	PC13-10	Actuated by A-F "ON" button	Control unit	P2-1, P2-2, P2-3. P27 relay off and limiting resistors on. P2-4, P2-5, P2-6. Switching to rate gyro system.

1	2	3	4	5	6
P3	P3-10	Actuated by	Control	P3-1, P3-2. Hand-grip bank con-	
		A.P. "ON"	unit.	trol switching.	
		button.		P3-3, P3-6. Hand-grip pitch con-	
				trol switching.	
				P3-4. "READY" light off and P1,	
				P2, P3, P15, P18, P20, P32 relays	
				interlocking circuit on.	
				P3-5. Prepares relay P6 for	
				switching on at coordinated turn.	
P15	PCM-3	Actuated by	Control	P15-1. Prevents coupling with	
		A.P. "ON"	unit.	A.P. on.	
		button.		P15-2. Direction channel nega-	
				tive feed-back switching.	
P18	PCM-1	Actuated by	Control	P18-1. Bank channel negative	
		A.P. "ON"	unit.	feed-back switching.	
		button.		P18-2. Pitch channel negative	
				feed-back switching.	
P20	P30-6	Actuated by	Control	P20-1. Decreases direction	
		A.P. "ON"	unit.	channel angle signal steepness	
		button.		to preselected value.	
				P20-2. Prevents A.P. to be	
				switched on with "ON" key	
				shown out as relay (P12) is	
				actuated and by contact P32-3	
				disconnects + 27 V.	

1	2	3	4	5	6
	P32	PCM-1	Actuated by A.P. "ON" button	Vibrator	from "ON" buttons and lights (J1 and J3). P32-1, P32-2. Switching to vibrator circuit.
2	P4	PC13-10		Control unit.	P4. Inoperative for this autopilot.
	P5	PC13-10		Control unit.	P5. Inoperative for this autopilot.
3	P6	PC13-10	Actuated by contacts (P16-2, P17-2) at coordinated turn	Control unit	P6-1, P6-4. Direction synchronizing mechanism potentiometer to turn magnetic amplifier switching. P6-3, P6-5. Direction channel angular velocity signal to common multi-turn winding switching and sending this signal to H.K. filter. P6-6. Direction synchronizing mechanism motor to turn magnetic amplifier switching.
4	P7	PC13-10	Actuated by "RETURN TO LEVEL FLIGHT" button	Control unit	P7-1. Relays (P1, P2, P3, P15, P18, P20, P32) group switching. P7-2. Relays (P8, P30) and relay (P7) interlocking circuit switching.

1	2	3	4	5	6
					E7-3, E7-5. Hand-grip bank and pitch control de-energizing and bank and pitch synchronizing mechanisms segments assemblies energizing. E7-4. Relay (P27) interlocking to prevent its actuation due to relay in actuation of relay (E7) and switches relays group and prevents altitude corrector switching off on return to level flight mode at involuntary movement of pilot's hand-grip for pitch. E7-6. Altitude corrector off when returning to level flight.
P8	PCM-2	Actuated by "RETURN TO LEVEL FLIGHT" button.	Control unit.		P8-1. Navigator's control knob potentiometer de-energizing.
P20	P20-6	Actuated by "RETURN TO LEVEL FLIGHT" button.	Control unit		P30-1. Control knob phase to bank synchronizing mechanism motor switching. P20-2. Pitch synchronizing mechanism motor phase switching on.

1	2	3	4	5	6
5	P9	PCM-2	Actuated by cage button	Control unit	P9-1. Relay (P10) interlocking off. P9-2. M.V.G. quick erection switching on at caging.
6	P10	PCM-2	Actuated by M.V.G. segments when 70° pitch angle is exceeded.	Control unit	P10-1. Lights (M and M) or M, M, M, M) off - M.V.G. knocking-off indication. P10-2. Relay (P10) interlocking.
7	P11	PCM-2	Actuated by pilot's hand-grip segments assembly.	Control unit.	P11-1; P21-1. Altitude corrector off at pitch control.
8	P12	PCM-2	Actuated at 36 V, 400c.p.s.	Control unit.	P12-1. Disconnects "+27 V" from A.P. "ON" button and lights (M, M) at time relay when switching power supply on.
9	P13	PCM-2	Actuated by relay (P27) contact	Control unit	P13-1. Disconnects "+27V" from A.P. "ON" button and light "READY" (M).
10	P14	PCM-2	Actuated with control panel "POWER" switch on.	Control unit.	P14-1. Prevents engagement of A.P. with M.V.G. plug connector disconnected. P14-2. Switches on relay TRK-55H supplying A.C. to autopilot.

- 39 -					
1	2	3	4	5	6
11	P16, P3C-6	Actuated by	Control	P16-1 or P17-1. Supplies	
	P17, P3C-6	pilot's hand-	unit.	a portion of bank signal	
		-grip or navi-		to pitch channel to com-	
		gator's control		pensate altitude loss at	
		knob.		turn.	
				P16-2, P17-2. Relay (P6)	
				on at turn.	
12	P19, P3C-6	Actuated with	Control	P19-1. Hand-grip bank con-	
	P29, P3C-2	switch (B2)	unit	trol de-energizing and	
		in "NAVIGATOR"		bank synchronizing mechan-	
		position		ism segments assembly	
				energizing.	
				P19-2. Relay (P28) on to	
				energize navigator's knob	
				after returning to level	
				flight from bank.	
				P29-1,2. Control knob	
				phase to bank synchronizing	
				mechanism motor switching.	
13	P22, P3C-2	Actuated when	Control	P22-2. Relay (P24) inter-	
		returning to	unit	locking circuit on and	
		level flight		supplies "+27 v" to alti-	
		from pitch or		tude corrector clutch.	
		with "AK"			
		button pressed			
14	P23, P3C-6	Actuated with	Control	P23-1, P23-2. Switch over	
	P24, P3C-6	contact (P28-2)	unit	altitude compensation	
		closed.		windings from bank synchro-	
				nizing mechanism potenti-	
				ometers to navigator's knob	
				potentiometer.	

2	3	4	-40-	5	6
					P24-1 switches over interlocking circuit of return-to-level-flight relays (P7,P8,P30) from normally-closed portion of pilot's switching button to normally-closed portion of navigator's switching button.
					P24-2. supplies "+27 V" to control panel switch "NAVIGATION" to prevent disconnection of "+27 V" from this switch due to relays (P25,P8,P30) actuation.
P25	PCM-2	Actuated by	Control	P25-1, P26-1. Prevent	
P26	PCM-2	navigator's	unit	control transfer to navigator if his knob is turned.	
		knob segments,		P25-2, P26-2. Switch on	
		assembly.		relays (P25, P26) when A.F. is controlled by navigator's knob.	
P27	Special	Actuated with	Control	P27. Relay (P27) on.	
	relay	control windings of servo units polarize or relays energized.	unit		
P28	PCM-1	Actuated with	Control	P28-1. Prevents transfer of	
		contact (P12-2) closed.	unit.	direction channel to synchronizing navigator's knob in- voluntarily moved from neutral position. P28-2. Switches relay (P28) on.	

VII. DESCRIPTION AND PURPOSE OF THE AUTOPILOT TRIMMING POTENTIOMETERS

To facilitate using the autopilot diagram, given below are trimming potentiometers with their functions indicated. (Given in brackets are designations of the trimming potentiometers shown in the control unit wiring diagram.)

- HI-1. - designed for centering the ailerons and located in the control panel labelled "K" (Bank).
- HI-2. - designed for selecting a pitch angle when returning to level flight and located in the control panel labelled "T" (Pitch).
- HI-3. - designed for centering the direction channel magnetic amplifier and located in the control panel labelled "H" (Direction).
- H2-1 (H4)
 - H2-2 (H5)
 - H2-3 (H6)
 used for regulating angular velocity ratio in bank, pitch and direction channels respectively.
- H3-1 (H12)
 - H3-2 (H13)
 - H3-3 (H14)
 used for balancing the phase sensitive rectifiers (H20, H21, H22 located inside the control unit).
- H4-1 (H20)
 - H4-2 (H21)
 - H4-3 (H22)
- H5-1 (H15)
 - H5-2 (H16)
 used for regulating the bank and pitch angles zone required for engaging the autopilot.
- H6-1 (H7)
 - H6-2 (H8)
 used for regulating the bank and pitch angle ratio.
- H7-1 (H1)
 - H7-2 (H2)
 - H7-3 (H3)
 used for regulating the servo amplifier gain factor.

- H8-1 (H10)
 H8-2 (H11)

} - used for regulating the signal value supplied from the pilot's hand-grip to bank and pitch channels magnetic amplifiers respectively.
- H8-3

- used for centering the magnetic amplifier with internal feed-back. Located in the magnetic amplifier.
- H10-1 (H12)

- used for setting the maximum bank angle when controlled by the navigator's knob.
- H10-2 (H13)

- used for regulating the value of altitude compensation signal from the navigator's knob. Located on bottom of the control unit labelled "KOMP".
- H11-1 (H14)
 H11-2 (H15)
 H11-3 (H16)

} - used for regulating the shifting voltage of the detectors valves in the bank, pitch and direction channels. Located inside the control unit.
- H12-1 (H17)

- used for regulating the angle ratio in the direction channel.
- H13-2 (H18)

- used for regulating the return-to-level flight rate when recovering from a positive pitch. Located on the bottom of the control unit labelled "I.KOMP."
- H14-2 (H19)

- used for regulating the value of altitude compensation signal from the pilot's hand-grip.
- H19-1
 H19-2
 H19-3

} - used for regulating the amplitude of the vibrator output signals to the bank, pitch and direction channels respectively. Located in the vibrator.
- H20

- used for regulating the frequency of signals supplied by the vibrator. Located in the vibrator.
- H22-2 (H17)

- used for regulating the altitude signal from the altitude corrector.

- H23-1 (H23) - used for regulating the return-to-level-flight rate when recovering from a bank. Located in the bottom of the control unit labelled "I_{KP}".
- H23-2 (H24) - used for regulating the return-to-level-flight rate when recovering from diving. Located in the bottom of the control unit labelled "I_{HPK}".
- H24-1 (H26) - used for regulating the bank pitch synchronizing mechanisms rotation speed by the pilot's hand-grip.
- H24-2 (H27) - Located on the bottom of the control unit labelled "PK_p" (for bank) and "PP" (for pitch).

VIII. PURPOSE, PRINCIPLE OF OPERATION AND DESIGN OF AUTOPILOT UNITS

1. Master Vertical Gyro (HVB-2)

The master vertical gyro (Fig.6) is used in the autopilot as a sensitive element and serves for measuring angles of aircraft deviation from vertical (bank and pitch angles).

The master vertical gyro is a two-gyro system with power stabilization which is vertically corrected by a liquid level switch. The signals proportional to bank and pitch angles are picked up from the potentiometers installed on the measuring axes of the master vertical gyro.

Principle of operation of the master vertical gyro is shown in the kinematic diagram, Fig.7.

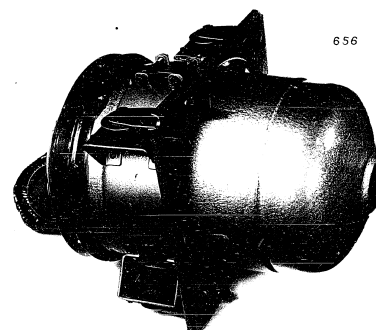


Fig. 6. External View of Master Vertical Gyro

The gyro-stabilized platform (1) is an inner gimbal ring and consists of two gyros (2) and (3), correction elements (8, 9, 10) and torque motor (5). The vertical axis of the platform is stabilized vertically to the earth's surface.

Rotation of the outer gimbal ring (15) in the casing (18) is not limited. Rotation of the platform (1) about Y axis is limited within ± 70 deg.

The X axis of the outer gimbal ring is directed along the aircraft longitudinal axis and the bank angle signals are picked-up from this axis by the potentiometer (11); the pitch angle signals are picked-up from the inner Y axis by the potentiometer (12).

The gyros (2) and (3) mounted on the platform (1) are permitted to turn through the angles of $\pm 2.7^\circ$ about X_1 and Y_1 axes which are called precession axes.

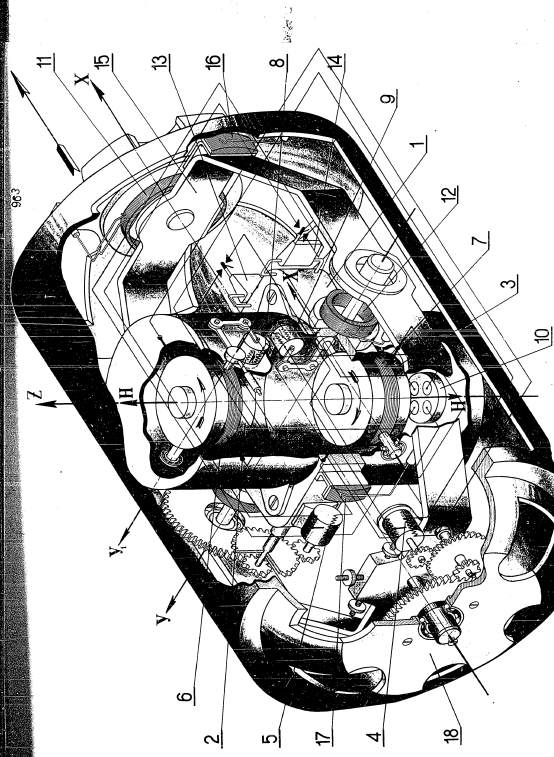


Fig. 7. Schematic Kinematic Diagram of Master Vertical Gyro

To erect a torque about the measuring axes whether it is due to friction or otherwise, causing a precession of the platform there are two torque motors (4) and (5).

The torque motor (4) is attached to the outer gimbal ring and connected to the casing via the reduction gear. The torque motor (5) is secured on the platform and connected to the outer gimbal ring via the reduction gear.

Installed on the gyro (2) casing is the potentiometer (6) which gives a signal to the torque motor (4), and installed on the gyro (3) casing is the similar potentiometer (7) which controls the torque motor (5). The wipers of these potentiometers are connected with the platform.

The gyro (2) together with the outer gimbal ring and torque motor (4) form a single-axis stabilizer system which stabilizes the platform (1) about X axis. The gyro (3) together with the platform and torque motor (5) form a single-axis stabilizer system which stabilizes the platform about Y axis.

On the whole the platform (1) is stabilized in space and its characteristics are almost the same as those of a free gyro (with the erection cut-out).

Let us examine the operation of the torque system in the master vertical gyro.

Suppose, that some distribution's torque M occurs about X axis of the outer gimbal ring. This torque through the bearings of the Y axis of the platform and bearings of the Y_1 axis of the gyro (2) acts on the gyro (2).

Under the action of the torque M the gyro (2) begins to precess about the Y_1 axis.

When the gyro (2) is drifted a signal, proportional to the angle of the gyro deviation from zero position, is picked-up from the

wipers of the potentiometer (5). The signal is fed to the torque motor (4) which creates, on the outer gimbal ring axis, an erecting torque opposite to the distributing torque M . When the distributing and erecting torques are equalized the gyro (2) stops precessing and it remains deviated through some angle about the Y axis of precession. In this case the platform (1) under the action of the torque M does not change its initial position.

After the action of the torque M is stopped the gyro (2) returns to zero position under the action of the erecting torque of the torque motor.

The erecting torque system consisting of the gyro (5) and torque motor (5) operates in the same manner under the action of distributing torques on the platform about the X axis.

Thus, due to the erecting torque system the platform (1) keeps its stable position in space under the action of distributing torques about measuring axes.

To keep the gyro-stabilized platform vertical the master vertical gyro is provided with erecting system consisting of the liquid level switch (10) and two torque motors (8) and (9).

The torque motor (8) is hinged to the gyro (2) case axis, the torque motor (9) is hinged to the gyro (3) case axis.

The correcting process in the master vertical gyro is similar to that for one-gyro verticals, where the erection torque applied to the inner gimbal ring axis causes a precession of the gyro about the outer gimbal ring axis.

When the platform (1) is tilted through some angle from vertical, i.e., about X axis, the liquid level switch mounted on the platform sends a signal to the torque motor (8). This torque motor creates torque about the gyro (2) axis which will cause a precession of the platform (1) about X axis to the vertical.

wipers of the potentiometer (6). The signal is fed to the torque motor (4) which creates, on the outer gimbal ring axis, an erecting torque opposite to the distributing torque M . When the distributing and erecting torques are equalized the gyro (2) stops precessing and it remains deviated through some angle about the Y axis of precession. In this case the platform (1) under the action of the torque M does not change its initial position.

After the action of the torque M is stopped the gyro (2) returns to zero position under the action of the erecting torque of the torque motor.

The erecting torque system consisting of the gyro (5) and torque motor (5) operates in the same manner under the action of distributing torques on the platform about the X axis.

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To keep the gyro-stabilized platform vertical the master vertical gyro is provided with erecting system consisting of the liquid level switch (10) and two torque motors (8) and (9).

The torque motor (8) is hinged to the gyro (2) case axis, the torque motor (9) is hinged to the gyro (3) case axis.

The correcting process in the master vertical gyro is analogous that for one gyro vertical, where the erection torque applied to the inner gimbal ring axis causes a precession of the gyro about the outer gimbal ring axis.

When the platform (1) is tilted through some angle from vertical, i.e., about X axis, the liquid level switch mounted on the platform sends a signal to the torque motor (8). This torque motor creates torque about the gyro (2) axis which will cause a precession of the platform (1) about X axis to its vertical.

The erection of the platform about the Y axis is performed in the same way by the same liquid level switch (10) and torque motor (9).

Moments of friction in the measuring axes do not affect the platform precession, as they are compensated by the torque motors.

The master vertical gyro is provided with separate cutting out of the lateral and longitudinal erection to decrease the instrument errors at accelerations.

For fast erection of the platform (1) to the vertical the mechanical pendulums (13) and (14) located on the platform are used. Each pendulum operates only in one plane and has a contact device to which the voltage is supplied automatically at starting the master vertical gyro from the bimetallic relay located in the control unit, or when pressing the "CAGE" button at knocking off the master vertical gyro.

When tilting the platform about the X axis the pendulum (13) via its contact group switches the torque motor (4). Summed up on the torque motor are two signals: a signal from the erection torque potentiometer (6) and a signal from the pendulum (13) of the fast erection system.

The signal from the pendulum always exceeds in value the signal from the erection torque potentiometer and is of opposite direction.

Under the action of the summary torque of the torque motor (4) the gyro (2) begins to precess. The precession of the gyro does not stop even after the gyro is deflected up to a position corresponding to the maximum signal picked-up from the potentiometer (6). The gyro (2) continues to precess due to the excessive torque from the pendulum signal till it rests on the restrictor.

In this case the platform will lose its gyroscopic properties about the X axis and begin to move rapidly to the vertical position as a common body.

The fast erection of the platform about the Y axis is performed in

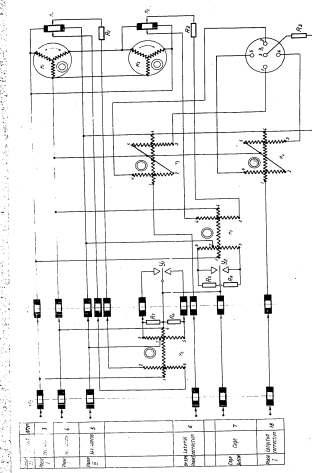


Fig. 8. Schematic Wiring Diagram of Master Vertical Gyro

the same way by the pendulum (14) and torque motor (5).

The fast erection system or cage erect the platform (1) to the vertical from any position within the master vertical gyro accuracy $\pm 1.5-2^\circ$. Further fine erection of the platform to the vertical is performed by the erecting system.

The fast erection system of the master vertical gyro erects the platform (1) in a position close to the vertical with no acceleration and irrespective of the instrument casing position.

The potentiometers (16) and (17) are of precision type with winding angle of $\pm 10^\circ$. The potentiometers (16) and (17) and resistors in the control unit form bridges the output of which is terminated with "K", "Op" and "T" terminals in the control unit.

The master vertical gyro is set to horizontal position by means of the precision potentiometers when the aircraft is in level flight position.

The master vertical gyro wiring diagram is given in Fig. 8, and the potentiometers diagram - in Fig. 9.

TECHNICAL DATA OF MTB-2 MASTER VERTICAL GYRO

1. Power supply:
 - a) from A.C. 3-phase source of $16 \text{ V} \pm 10\%$, $400 \text{ c.p.s.} \pm 2\%$
 - b) from D.C. aircraft electrical system of $27 \text{ V} \pm 10\%$.
2. Current drawn in the operating rating is not more than $\pm 1.1 \text{ A}$ in each phase.
3. Accuracy of maintaining the vertical on the swinging base, with a swing angle of 5° and a period of $10-15 \text{ sec.}$, is not more than ± 10 angular min.
4. Instrument error after performing turns of 10 min. duration (maximum) at an angular velocity more than 0.3 deg./sec. , is not more than $\pm 2^\circ$.

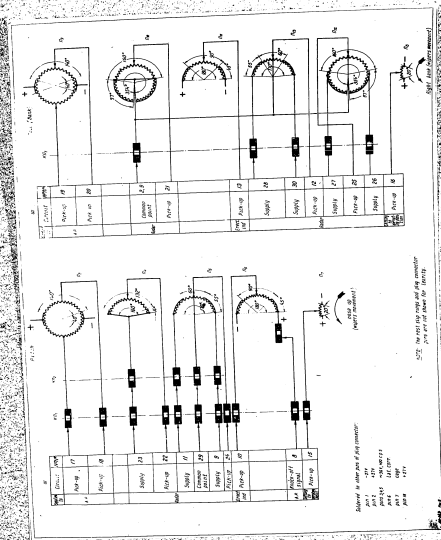


Fig. 8. Schematic wiring diagram of Master Vertical Gyro Potentiometers

(In this case the lateral erection must be cut-out by the BK-53PB erecting cut-out switch).

5. Operating angle limit range:

- a) bank - $\pm 180^\circ$ (signal output $\pm 70^\circ$)
- b) pitch - $\pm 70^\circ$

6. Weight - not more than 7.8 kg.

2. JVC-970B RATE GYRO UNIT

The rate gyro unit (Fig.10) is designed to give signals proportional to the angular velocity of the aircraft about its three main axes.

A two-axes-of-freedom gyro is used for measuring the aircraft angular velocity. If this gyro is turned about its measuring axis, the gyro rotor, by the law of precession, will precess about the axis perpendicular to the measuring axis till the precession moment is equal to the counter moment of the restoring springs. As the springs have a linear characteristics, the angle of precession of the gyro rotor about the precession axis is proportional to the gyro angular velocity about the measuring axis.

The aircraft angular velocity is measured by an induction potentiometer the rotor of which is attached on the gyro precession axis.

Mounted on the aluminium base (2) are three individual rate gyros (3) for three measuring axes and a liquid level (4) used for installation the rate gyro unit in the aircraft. For convenience of mounting the plug connector is secured on the cable (1).

The rate gyros are different from each other by location of the rotor axis in the casing. The rotor axis of the roll and pitch gyros is vertical, of the directional gyro - horizontal.

Given in Fig.11 is a roll and bank rate gyro. The basic element of the rate gyro is a gyro assembly (4).

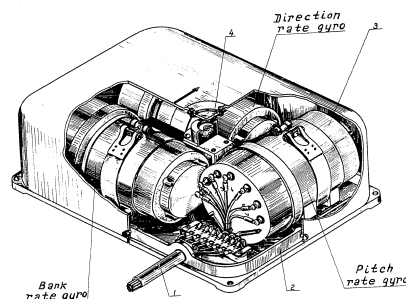


Fig. 10. Rate Gyro Unit

The gyro assembly is an asynchronous electric motor with a kinetic moment of 500 gm-cm/sec., the rotor and stator of which are placed in a special casing. The gyro assembly is mounted in the case (10) on bearings (1) and is held in its initial position by two spiral springs (6).

Attached to the gyro assembly axle (from the side opposite to the instrument cover) is the rotor (2) of the induction potentiometer, the stator (3) of which is installed in the instrument casing.

The gyro assembly by means of the arm is connected with the piston of the pneumatic damper (5) which is used for damping the gyro assembly self-oscillations.

To prevent the rate gyro operation from affecting of the flight altitude changing the rate gyro is placed in the hermetically sealed casing filled with nitrogen.

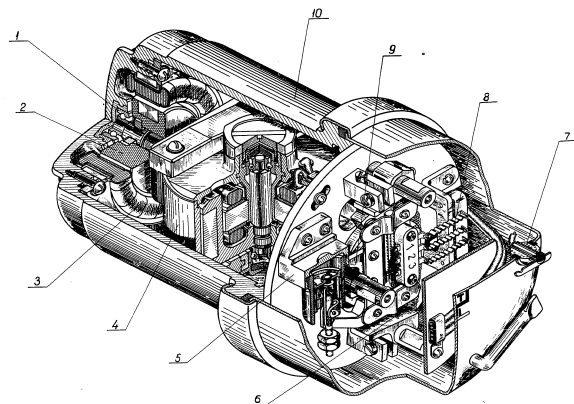


Fig. 11. Rank and Pitch Rate Gyro

Power to the gyro motor is supplied through the elastic brass springs (8).

Installed on the instrument cover is a stop with a rubber bumper, and on the gyro assembly - the restrictor (9) limiting the gyro assembly turning angle within $\pm 8^\circ$, which corresponds to the angular velocity of the rate gyro about the measuring axis of 13-20 deg./sec.

The wires lead from the casing through special glass insulator (7).

The schematic wiring diagram of the rate gyro unit is shown in Fig. 12.

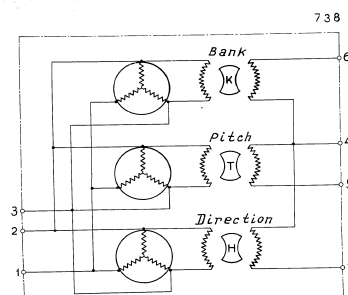


Fig. 12. AVO-S706 Rate Gyro Unit Wiring Diagram

TECHNICAL DATA OF AVO-S706 RATE GYRO UNIT

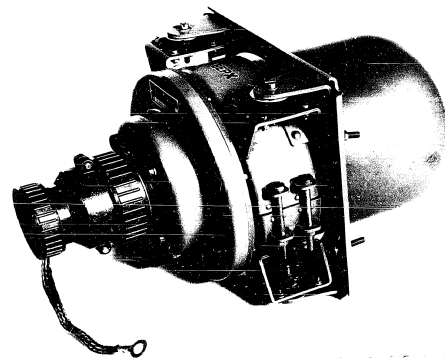
1. Angular velocity sensitivity 0.1 deg./sec.
2. Gyros kinetic moment 500 gm-cm/sec.
3. Frequency of gyro self oscillation 8-10 c.p.s.
4. Angular velocity measurement range 0.1-18 deg/sec.
5. Power supply 36 ± 2 V, 400 ± 8 c.p.s.
6. Induction potentiometer output
signals steepness (for a load
of 2.2 kohms) $0.7 \frac{V}{deg/sec.}$
7. Weight 2.6 kg.

3. KB-11 ALTITUDE CORRECTOR

The altitude corrector (Fig. 13) is designed for giving signals (to the autopilot) of the barometric altitude deviation from the preset value.

The altitude corrector is a follow-up system, the block diagram of which is shown in Fig. 14.

The aneroid assembly is a transmitter which measures the barometric pressure changing versus flight altitude.



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Fig. 13. KB-11 Altitude Corrector

The movement of the aneroid assembly causes the proper turn of the coil (armature) of the induction transmitter. The follow-up system operates from the induction transmitter unbalance signals.

The voltage, proportional to the turn angle of the induction transmitter coil relative to the core, is supplied to the amplifier and from the amplifier output to the control winding of the electric motor which, through the reduction gear, turns the induction transmitter core till the transmitter and coil unsynchronizing angle is eliminated.

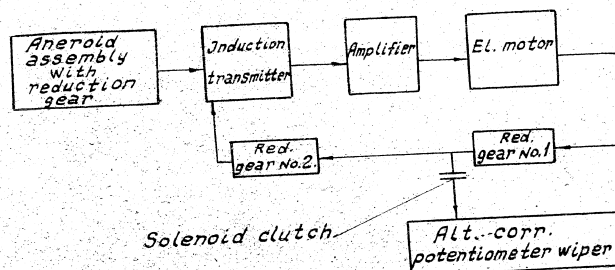


Fig. 14. Altitude Corrector Block Diagram

With the clutch disengaged the centering spring automatically set and hold this wiper on the potentiometer in zero position (against the middle point) thus provides a possibility after engaging the clutch, of picking-up a signal whose corresponding value and phase) to the aircraft altitude deviation from the established value when the clutch is engaged.

To increase the moment of the aneroid they are assembled from two aneroid assemblies (4).

The female apparently rode, although the bird was blind and compensatory, turn the wheel of the motor. When the bird was engaged to it, the bird was placed on the small track and it negotiated with it for a while. It was then removed. The bird was taken by the motor to the end of the track with the female. The bird could not attend to it.

[illegible]

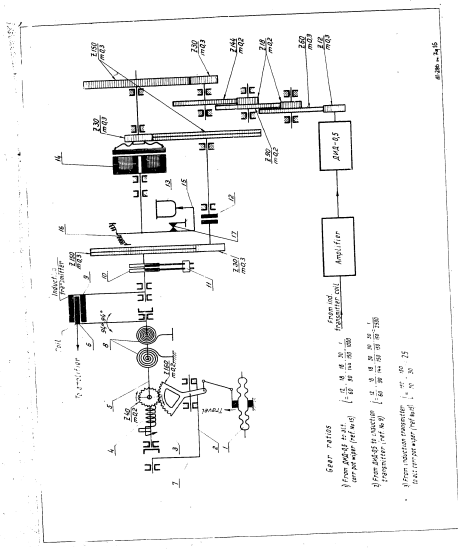


FIG. 16. Kinematic diagram of attitude corrector

Two hairsprings (8), which supply current to the induction transmitter coil, keep all parts of the aneroid mechanism tight against one another.

The induction transmitter (9) core is attached to the shaft connected with the reduction gear.

The induction transmitter core coils are supplied through the slip rings (10) and brush assembly (11).

To avoid the instrument failure in case of flight altitude is more than 20,000 m and with wrong power supply, the reduction gear final pair connected with the altitude potentiometer wiper is provided with a friction coupling (12) which slips when the wiper reaches the restrictors. The potentiometer (13) of the altitude corrector is wound on the frame attached to the casing.

When switching on the solenoid clutch (14) the altitude corrector (15) potentiometer wiper connects to the reduction gear and moves together with the induction transmitter core.

The altitude corrector potentiometer is connected with springs (16) which, with the clutch disengaged, return the wiper to zero position.

When the altitude corrector potentiometer wiper returns to zero position the contact group (17) is closed. The wiper turn angles are limited by restrictors.

To prevent the altitude corrector from damage when flying with the instrument de-energized, the links, transmitting the aneroid diaphragms travel to the induction transmitter coil, are provided with slots corresponding to the aneroid diaphragms travel.

At the air or at descent with the altitude corrector de-energized the aneroid diaphragms travel is transmitted through the sector to the pinion, moves the coil up to stop and then causes turning of

the pinion, connected with the shaft by a spiral spring.

The amplifier is mounted inside the altitude corrector and it is a two-stage transistor (Fig. 15).

The first stage is based on circuit with a common emitter on H13A(III) triode.

R resistor - feed-back resistance designed for thermostabilization.

R_1 resistor is designed to limit the slip ring voltage.

The second stage is of push-pull type and is based on H203(II) triodes. The base bias is supplied through H1-A1 nonlinear resistances which change their value due to temperature change, thus stabilizing the amplifier operating point with the temperature changing.

Connected in the emitter circuits are R_2 resistors which serve simultaneously as elements of automatic base bias and a current negative feed-back.

R_3 resistor provides voltage negative feed-back, thus the repeater gain with the temperature changing is stabilized.

The JMM-0.5 electric motor control windings connected seriesly between each other and directly to the output triode collector circuits are a load of the amplifier output stage.

C_1 capacitor is a separative capacitor in the input circuit.

C_2 capacitor is used for resonance tuning of the amplifier output circuit.

C_1 and C_2 capacitors are located outside the amplifier.

The altitude corrector is hermetically closed by a cover with rubber sealing. To connect the instrument inner cavity to the static line the flange is provided with a pipe connection.

APP-11 ALTITUDE CORRECTOR TECHNICAL DATA

Operating range from 0 to 20,000 m.

2. Power supply:

- a) 36 V $\pm$ 10%, 400 $\pm$ 8 c.p.s. A.C.
- b) 27 V $\pm$ 10% D.C.

3. Current drawn:

- a) A.C. - 0.3 A in each phase
- b) D.C. - 0.4 A

4. Maximum follow-up speed corresponds to vertical speed of 200 m/sec.

5. Maximum output voltage picked-up from the altitude corrector potentiometer (ΔH signal) is $\pm$ 13.5 V D.C.

6. Full operating range of the altitude corrector potentiometer is $\pm$ 160 - 320 m. (the last figure refers to the altitude of 20,000 m.)
linearity range is $\pm$ 130-320 mm. (the last figure refers to the altitude of 20,000 m.).

7. Instrument zero changing due to the temperature changing - $\pm$ 1 m/sec

8. Dead zone of the instrument at altitudes not more than:

- for 1 km altitude $\pm$ 5 m. of altitude
- for 12 km altitude $\pm$ 10 m. of altitude
- for 20 km altitude $\pm$ 25 m. of altitude

9. Weight 2.5 kg.

4. AV-826 CONTROL UNIT

The control unit (Fig. 17 and 18) comprises the autopilot elements which provide:

- 1. Electrical connection of all the autopilot units between each other;
- 2. Power supply distribution to all the autopilot units;
- 3. Transformation, summing-up and amplification of control signals;
- 4. Automatic synchronizing of the autopilot elements;

5. Necessary switching and interlocking at all operating modes of the autopilot.

The control unit consists of the following elements: amplifiers unit, magnetic amplifier with inner feed-back, three synchronizing mechanisms, some standard relays and potentiometers, elements composing phase-sensitive amplifiers.

The elements of the phase-sensitive amplifiers are: 6 transformers, 16 RT-1 germanium diodes, 6 potentiometers.

The control unit is made so that the connection of all the autopilot elements is concentrated in it.

The control unit is a welded frame attached to which is a panel with the synchronizing mechanisms and other elements.

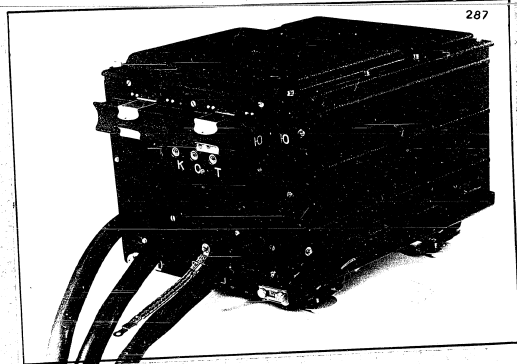


Fig. 17. Control Unit

Mounted on the control unit face panel are two plug connectors for checking the control unit and three cables terminated with plug connectors to connect with other units of the autopilot, and three special terminals to check the proper installation of the master vertical gyro in the aircraft.

Three other walls form a removable H-shaped housing. On the top the unit is closed by the cover with a special access door for adjusting resistors. To install the control unit in the aircraft the unit is provided with a shock mounting. The unit is secured to the shock mounting by quick-mounting device.

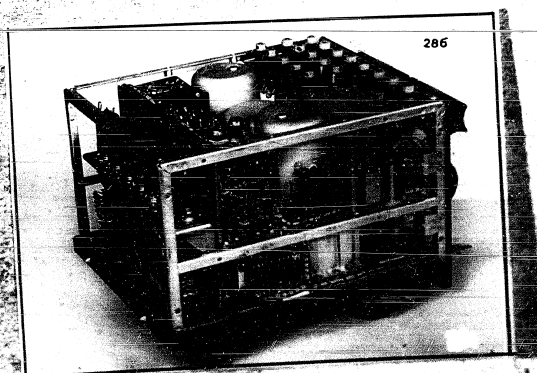


Fig. 18. Control Unit with Housing Removed

a) Bank and Pitch Synchronizing Mechanism

Bank and pitch synchronizing mechanisms are of similar construction and are the complete units (Fig.19). The synchronizing mechanism consists of two-phase induction electric motor (8) with reduction gear (1), potentiometer (4) and contact segments (2).

The field winding of the MM-0.5 electric motor is supplied with 36 V, 400 c.p.s. A.C. The reduction gear consists of four pair of cylindrical gears.

The bank and pitch synchronizing mechanisms differ from each other by their connection diagram (Fig.20 and 21) and the reduction gear ratio.

The bank synchronizing mechanism reduction gear ratio is $\frac{1}{728}$, the pitch synchronizing mechanism reduction gear ratio is $\frac{1}{2463}$.

Attached to the reduction gear outlet shaft are the wipers (3) of the potentiometer and segments. The permissible turning angle of the reduction gear outlet shaft limited by restrictors is $\pm 60^\circ$ from the middle position. To prevent the reduction gear from damage when the shaft reaches the limit turn angles, the outlet gear of the reduction gear is connected with the shaft by a friction coupling made of two steel-hardened discs (6) with the outlet gear (5) tightened between them.

The spring (7) creates the discs tightening force.

The synchronizing mechanism provides continuous compensation of all the signals supplying to the magnetic amplifier till the autopilot is engaged by the "A.P.ON" button. After engaging the autopilot the synchronizing mechanism motor can receive signals from the pilot's A.P. control hand-grip and in the "return to level flight" mode - from the segment device.

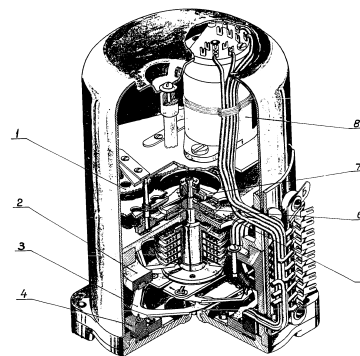


Fig. 19. Bank and Pitch Synchronizing Mechanism

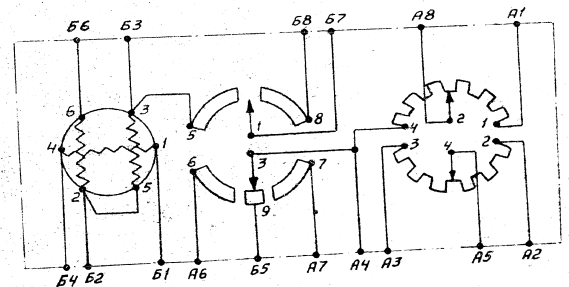


Fig. 20. Bank Synchronizing Mechanism Wiring Diagram

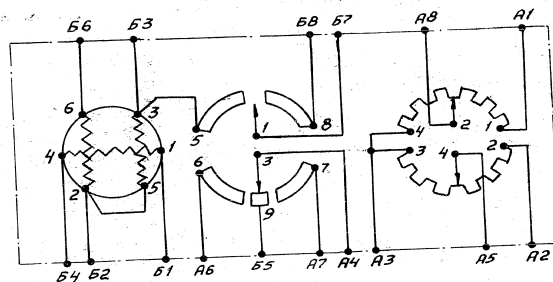


Fig. 21. Pitch Synchronizing Mechanism Wiring Diagram

The segment device of the bank synchronizing mechanism consists of two pair of contact segments and two wipers.

A pair of the segments having an insulating space of 1° - 2° is connected into circuit in the "return to level flight" mode. The second pair of the contact segments, used only in the bank synchronizing mechanism, makes necessary switchings at the aircraft turn.

Located in the centre of the insulating space is a contact, used only in the pitch synchronizing mechanism, providing automatic switching of the altitude corrector after the return to level flight mode is completed.

The potentiometer of the synchronizing mechanism is wound on two portions (150° of arc each) of the circular frame. Both the portions of the potentiometer are connected in a bridge.

b) Direction Synchronizing Mechanism

The direction synchronizing mechanism (Fig. 22 and 23) has mainly the same functions as the bank synchronizing mechanism.

The direction synchronizing mechanism reduction gear ratio is $\frac{1}{2463}$.

The direction synchronizing mechanism differs in construction from the bank and pitch synchronizing mechanism by the following:

1. No contact segments and friction coupling;
2. Potentiometer uniformly wound through the whole circumference;
3. Outlet shaft has no restrictors.

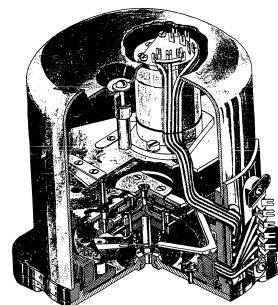


Fig. 22. Direction Synchronizing Mechanism

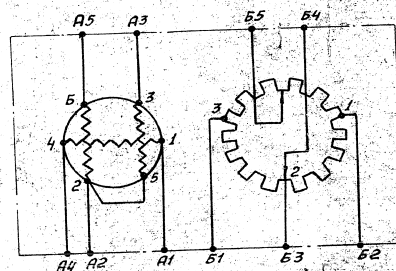


Fig.23. Direction Synchronizing Mechanism Wiring Diagram

c) Amplifiers Unit (Fig.24)

The amplifiers unit comprises the following:

1. Three magnetic amplifiers.
2. Three electron-tube amplifiers based on 6H11 valves, designed to amplify signals supplying from the magnetic amplifiers.
3. Three electron-tube detectors based on 6H11 valves the output of which is connected to the control windings of the relays of the servo units.
4. Power supply unit comprising the power transformer, rectifier, kenotron, impedance - capacitance filter.
5. Three transformers for supplying the magnetic amplifiers windings.

d) Magnetic Amplifier

The magnetic amplifier (Fig. 25) is made as a separate assembly and is a double choke placed in a casing and closed by a panel with terminals.

The magnetic amplifier is designed for summing-up, amplifying and transforming the D.C. control signals into A.C. signals.

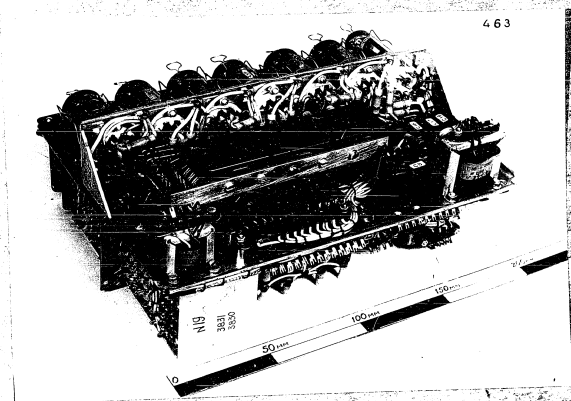


Fig. 24. Amplifiers Unit

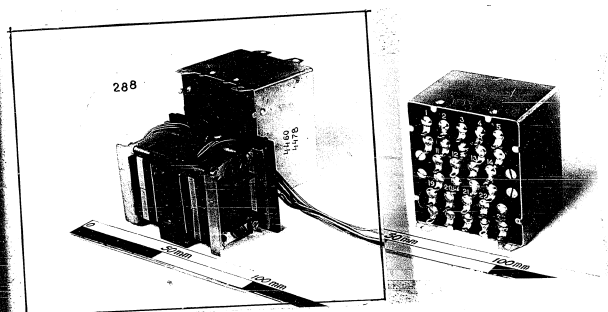


Fig. 29. Magnetic Amplifier

The principle of the magnetic amplifier operation is based on using the nonlinearity of ferromagnetic materials magnetization curve.

To understand the principle of the magnetic amplifier operation consider the core affected by simultaneous magnetizing by the direct and alternating magnetic fields. For different values of the direct component (B_0) of magnetic induction (Fig. 29) the intensity of magnetic field ($H \sim$) changing curve can be plotted neglecting the hysteresis effect.

The A.C. component of the magnetic field intensity ($H \sim$) is proportional to alternating current ($i \sim$) magnetizing the core.

As shown in Fig.26, with increasing in the direct component (B_0) of magnetic induction, created by magnetizing by direct current, the value of A.C. component ($H \sim$) and the magnetizing alternating current increase.

In the other words, the magnetic permeability of the core material for the A.C. component of magnetic flux decreases with increasing in the magnetizing direct current.

This magnetic amplifier is a bridge voltage amplifier and it consists of two cores the middle bars of which have D.C. windings, the side bars -- A.C. winding.

The A.C. windings connection diagram is shown in Fig.27.

Assume, that when the magnetizing D.C. current flows through the W_{n1} and W_{n2} windings, the magnetic fluxes $\Phi_{n1} = \Phi_{n2}$ directed on the arrow (see Fig.27) are induced in the cores.

As a result of this both cores have equal magnetic permeability and thus the reactances of $W_1 \sim$; $W_2 \sim$; $W_3 \sim$; $W_4 \sim$ windings are equal.

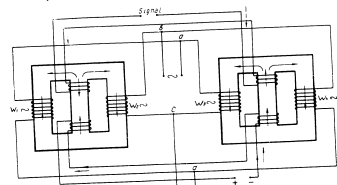
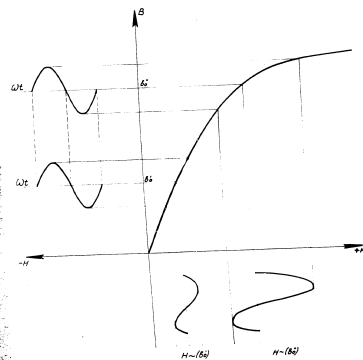
The A.C. windings connection diagram (Fig.27) shows that with equal resistance of these windings $U_{\text{output}} = 0$.

W_{1c} and W_{2c} windings are opposite connected and when D.C. current I_0 flows through them in the given direction, the magnetic fluxes (Φ_{1c} and Φ_{2c}), induced as a result of it, are added to the magnetizing flux (Φ_n) in core II and are subtracted in core I.

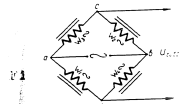
As a result of changing of the magnetic permeability the reactance of the $W_3 \sim$ and $W_4 \sim$ windings decreases and of the $W_1 \sim$ and $W_2 \sim$ windings increases, the bridge becomes unbalanced and a potential difference between points c and d occurs.

When changing the current I_0 direction the fluxes are added in core I and subtracted in core II, and a reverse phase voltage is appeared between points c and d of the bridge.

Magnetizing curve



AC bridge circuit diagram



If on the

the resulting control flux is equal to the algebraic sum of these windings fluxes.

Then, the magnetic amplifier provides summing-up, amplifying and transforming D.C. signals into A.C. signals.

The amplifier has 7 signal windings.

a) Principle of Electronic Amplifier and Detector Operation

The amplifier (Fig. 28) is based on a 6H11 double triode and is used for operation of the synchronizing mechanism motor and detector. A required gain factor is obtained due to a series connection of two stages.

The stage-to-stage transfer - a rheostat - capacitance type, the amplifier output - a transformer type.

The capacitor (C_3 , Fig. 28) is used for creating a resonance stage on the primary winding of the transformer, set for a signal frequency (400 c.p.s.). The resistor (R_2), shunting this stage, permits to obtain the minimum dependence of the gain factor on the signal frequency change.

The initial negative bias on the triodes grids is obtained automatically due to the voltage drop across the resistors (R_2 and R_4) in the cathodes.

To eliminate the effect of the negative feed-back created by this method of the initial bias setting, the cathodes of the two triodes are interconnected by the resistor (R_3). The appearing of the negative feed-back and the action of the resistor (R_3) can be explained as follows:

The alternating component of the first triode plate current, increases the voltage drop across the resistor (R_2).

This voltage is applied between the grid and cathode and its phase is opposite to the input voltage phase.

As a result of adding these voltages, the signal between the grid and cathode will be less than the input signal.

The same occurs in the second stage where the first triode output voltage is the input voltage and the negative signal is the voltage across the resistor (R_4).

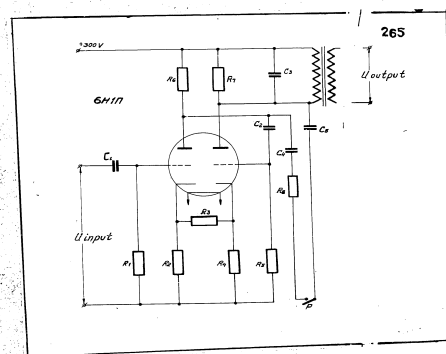


Fig. 28. Electronic Amplifier Schematic Diagram

It can be noted that the alternating component of the voltage across the resistor (R_4) of the second stage is opposite in phase to the alternating component of the voltage across the resistor (R_2) of the first stage and exceeds it due to the signal amplification by the first stage.

By selecting the resistor (R_3) connecting the second triode cathode with the first triode cathode it is possible not only to eliminate the alternating component of the voltage across the resistor (R_2) but obtain this resistor voltage being in phase with the input signal.

In the described system, the value of the resistor (R_3) is selected to completely compensate the negative feed-back.

Detector (Fig. 29) is based also on a 6H11 valve. The detector is used to convert (rectify) the voltage received from the amplifier and to obtain the power required to control the field of

With no signal the both triodes are blocked. It is provided by a comparatively high (about 12 V) negative voltage across the grids; this voltage being supplied by the potentiometer (III) through the resistor (R_B).

In this system the presence of plate current is a triode is possible only at a positive voltage simultaneously applied to the grid and plate.

The capacitors (C_4 and C_5) serve for smoothing the current pulsing in the loads (Z_{H1} and Z_{H2}).

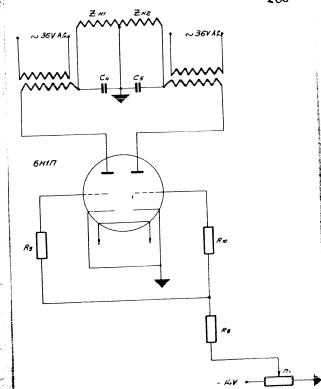


Fig. 29. Electronic Detector

78 —

78 —

- 78 —

78 —



78 —

f) Magnetic Amplifier with Internal Feed-Back

The magnetic amplifier (Fig.30) is a separate unit incorporating:

1. Amplifier consisting of two double chokes;
2. Power supply transformer;
3. Power with resistors;
4. Two brackets with selenium rectifiers;
5. Resonant capacitance;
6. Centering potentiometer.

The magnetic amplifier is used for amplifying and inverting the A.C. control signal, picked up from the direction synchronizing mechanism potentiometer, into the A.C. signal.

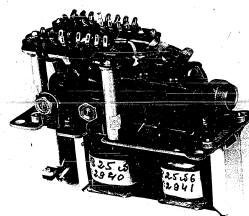
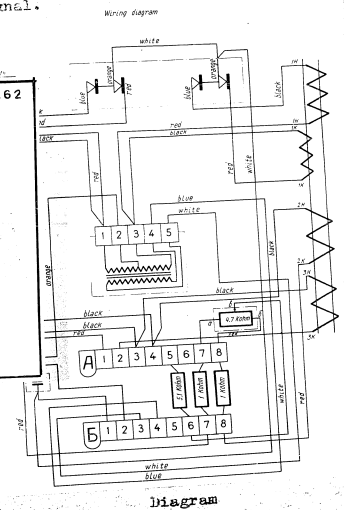


Fig.30. Magnetic Amplifier
with Internal
Feed-Back



The principle of the magnetic amplifier operation was described above.

The magnetic amplifier differs from that described above, in the internal feed-back obtained due to the constant component of the pulse current without special feed-back windings.

The windings connection diagram is shown in Fig. 31.

In this circuit the alternating current flows through the rectifiers (B_2 and B_4) and windings ($W \sim$) of the first cores (I) during one half-period. During the following half-period the current flows through the rectifiers (B_1 and B_3) and windings ($W \sim$) of the second cores (II). Thus, the pulse current flows in each A.C. winding; the constant component of this current is proportional to the load current. This constant component creates a magnetizing field of the feed-back.

With no signal, created in the cores are equal magnetic fluxes directed on arrow as indicated in Fig. 31.

As a result of this, the cores permeabilities are equal and, therefore, the reactances of all the windings ($W \sim$) will be equal too. The Fig. 31 illustrates that at the equality of this windings reactances, the voltage across the load will be zero.

With a signal applied (in the indicated direction) the magnetic fluxes (Φ) of feed-back and Φ_0 generated by the pulse current in the winding ($W \sim$) and by the control current in the winding (W_c) combine in direction in the left choke and in the right choke act in opposite directions.

Due to a change in the permeability, the reactance of the left choke winding ($W \sim$) will drop and the reactance of the right choke will considerably increase. At this time the current in the right choke winding ($W \sim$) will be small. A voltage appears across the synchronizing mechanism motor control winding.

When the direction of the signal is changed, the flux (Φ) of feed-back and the flux (Φ_0) will be summed up in the right choke and subtracted in the left choke.

An opposite phase voltage appears across the synchronizing mechanism motor control winding.

The auxiliary winding of initial magnetizing (IHM) with the centering potentiometer (R) serves for setting "zero" of the amplifier.

4) Phase-Sensing Rectifier

The phase-sensing rectifier is a unit which changes the polarity of the output rectified current if the input alternating current changes its phase 180° .

The phase-sensing rectifier of the AL-20A autopilot consists of the elements shown in Fig.32, "a".

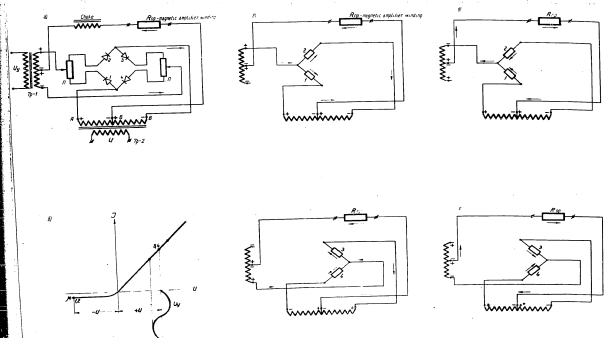


FIG.32. Phase-Sensing Rectifier

Study the system operation for one period of the alternating voltage.

U_y - control voltage from the rate gyro; U - supply voltage of the same frequency as U_y but greater in amplitude.

Assume that in the first half-period the polarity of the transformers output terminals corresponds to that indicated in Fig.32 "a".

The magnetic amplifier current generated by the voltage (U) is always equal to zero, as the two windings (AB and EB) of the transformer (2) create equal and opposite in direction currents for the given moment.

The current, generated by the voltage (U) from the terminal "A" to terminal "B" flows through the rectifiers (1 and 2) but not flows through the rectifiers (3 and 4) having large resistance.

Applied to the rectifiers (3 and 4) during this half-period is the voltage (U) of such a polarity at which they do not conduct the current i.e. are blocked.

Observe the possible flows of the currents generated by the voltage (U_y). At this it is necessary to take into account that the voltage (U) amplitude is considerably larger than the amplitude of the voltage (U_y) and, therefore, the rectifiers (1 and 2) are opened and pass the currents generated by the voltage (U_y) irrespective of the voltage polarity for the given half-period.

At the same time, the rectifiers (3 and 4) are blocked and do not pass the currents generated by the voltage (U_y).

The Fig.34 "d" illustrates that the operating point "H" of the rectifiers (1 and 2) at any $U_y < U$ remains on the characteristics conducting section, and the operating point of the rectifiers (3 and 4) at any $U_y < U$ remains on its non-conducting section.

The phase-sensing effect is obtained by selecting the voltage (U) exceeding the voltage (U_y).

If in the first half-period the rectifiers (3 and 4) are blocked they may be neglected.

See the corresponding simplified equivalent diagram shown in Fig. 32 "B".

The magnetic amplifier winding current is generated by the voltage $\frac{U_y}{2}$ picked up from the transformer (1) half winding.

For the second half-period, having changed the polarity across the terminals of the both transformers find that the rectifiers (1 and 2) are blocked and the rectifiers (3 and 4) are opened as shown in the simplified equivalent diagram Fig. 32 "C".

We see that the direction of the current flow in the second period does not change. Now, change the phase of the control voltage (U_y) by 180° . Then for the first half-period we obtain the simplified equivalent diagram shown in Fig. 32 "D" and for the second half-period - Fig. 32 "E".

Now, in the both half-periods with the phase (U_y) changed by 180° , the direction of the current flow in the magnetic amplifier winding is changed for opposite.

Thus, at the phase change by 180° , the rectified current polarity changes.

Used in the AN-28A autopilot as rectifiers are 2N-4 semiconductor diodes.

The potentiometers (Fig. 34 "a") are necessary for centering the phase-sensing rectifier and compensating the zero signal of the rate gyro; the diode is used for setting the rectified current pulsing.

5. PILOT'S A.P. CONTROL HAND-GRIP (PY-442E)

The control hand-grip is used for controlling the aircraft by the pilot through the autopilot. (Fig.33).

Operating this hand-grip the pilot can perform coordinated turns, ascending and descending spirals, and the aircraft pitch control.

The hand-grip position corresponds to the rate of the aircraft deviation from the initial bank and pitch positions.

The hand-grip is an electromechanical assembly. The hand-grip assembly is of conical shape with the domed hood (9), column (10) and ball-shaped handle (1).

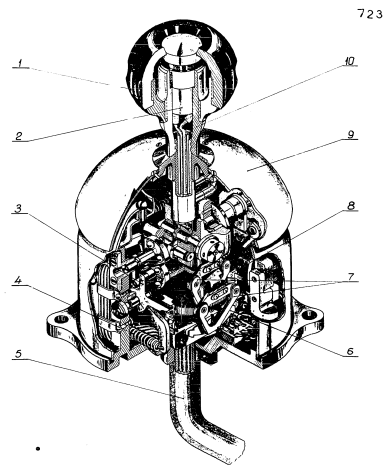


Fig.33. Pilot's A.P. Control Hand-Grip

Built-in the handle is the autopilot "OFF" button (2). The handle column is attached to an universal joint and can be shifted in any position from the neutral through an angle of $\pm 20^\circ$.

The levers (3) and springs (4) system returns the column to initial position.

With the hand-grip deflected, the spring forces increase proportional to the angle of deflection and the pilot feels when the hand-grip is moved from neutral position.

Attached to the column shaft are the wipers (7) of the potentiometer (8) and pitch segments (6) located on the moving assembly. The bank potentiometer and segments are attached to the hand-grip assembly base and their wipers on the universal joint moving part.

With the hand-grip in neutral position, the potentiometer and segments wipers rest on the insulated sections.

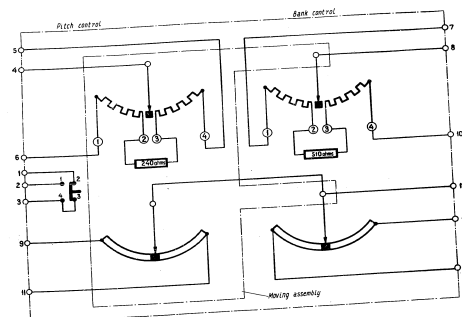


Fig. 34. Hand-Grip Wiring Diagram

The pitch and bank potentiometers have two (equal in resistance) windings insulated from each other.

Each potentiometer forms two arms of the bridge circuit with the control windings of the bank and pitch synchronizing mechanisms.

To ensure reliable operation of the system and to compensate the system insensitivity with the hand-grip deflected through a small angle, the potentiometer windings are interconnected by a 240-ohm constant resistor. With the hand-grip deflected in either direction, as soon as the wiper contacts the winding of one of the potentiometer arms, the motor receives a voltage sufficient to remove insensitivity condition. Simultaneously, by-passing the synchronizing mechanism, a signal is sent through the magnetic amplifier; this signal deviates the aircraft proportionally to the angle of the hand-grip deflection.

The pitch segments assembly is designed for butting out the altitude corrector when the hand-grip controls pitch.

The bank segments assembly is not employed in this version of the autopilot.

All the elements of the hand-grip assembly are mounted on the cast aluminium base. To facilitate wiring the hand-grip is fitted with an angle plug connector.

The hand-grip wiring diagram is shown in Fig. 3a.

TECHNICAL DATA (T-442E)

1. Maximum angle of hand-grip deflection from neutral position + 20°
2. Potentiometers data:
 - a) each winding resistance 300-200 ohms
 - b) wire used on potentiometers UZM, 0.07 mm²
3. Hand-grip assembly weight 1 kg.

6. NAVIGATOR'S TURN CONTROL KNOB (PE-828A)

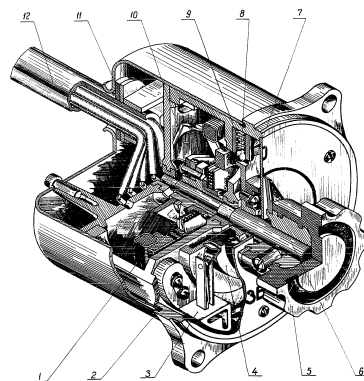
The navigator's knob (Fig.35) is used for performing coordinated turns.

The knob position corresponds to the aircraft bank and rate of turn.

The navigator's control assembly consists of the potentiometer (1), two contact groups (3) controlled by the cam (4) and wipers (19) attached to the shaft (6).

The centre section of the potentiometer is short-circuited at an angle of $\pm 4^\circ$.

With the knob turned in either direction, the contact groups close before the potentiometer wiper has left the soldered section.



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Fig. 35. Navigator's Turn Control Knob

When transferring the control to the navigator, the knob must be set in zero position.

If, before transferring the control, the knob was not in zero position, the contact groups (3) open the control-to-navigator transfer circuit.

Mounted on the knob shaft is the steel cam (7) locking the knob in zero position by means of the ball (8) and spring (9).

Besides, the cam and ball create additional friction holding the knob in other positions.

Mounted on the shaft is the knob (5) with a pointer. All the elements of the control knob assembly are mounted on the cast aluminum base.

The rubber gaskets (2 and 11) protect the knob assembly interior from dust.

To facilitate connection of the knob, the plug connector is attached to the cable harness (12) 300 mm. long.

The knob wiring diagram is shown in Fig.36.

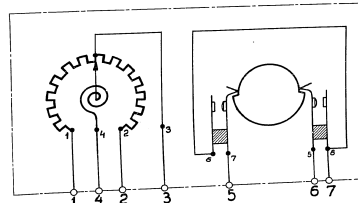


Fig.36. Navigator's Knob Wiring Diagram

TECHNICAL DATA (PL-828A)

1. Angle of knob turn from zero position $\pm 135^\circ$
2. Potentiometers data:
 - a) resistance of each arm of potentiometer
(from soldered section to extreme tapping) 450 ± 90 ohms
 - b) wire used on potentiometer ПЗК, 0.4 mm. dia.
3. Knob assembly weight 0.4 kg.

7. AUTOPILOT CONTROL PANEL (HV-822A)

The control panel (Fig.37) is a panel carrying the autopilot elements used for the following functions:

- a) switching the A.P. power supply on (power switch)
- b) indication of the A.P. readiness for engagement ("READY" amber light).
- c) indication that the autopilot is engaged by the "ON" buttons ("ENGAGED" green light).
- d) indication of the M.V.G. gyro unit position (indicator with "PITCH" on button.)
- e) indication of the M.V.G. knocking off ("M.V.G." green light)
- f) engaging the M.V.G. cage if the M.V.G. is knocked off ("CAGE" button).
- g) transferring the control to the navigator ("CONTROL TRANSFER" switch).
- h) indication that the control is transferred to the navigator ("NAVIGATOR" amber light).
- i) centering the aircraft by the potentiometers "R" (Bank), "Pitch" and "H" (Direction) when the autopilot operates in the

return to level flight made with the

"RETURN TO LEVEL FLIGHT" button pressed and at a coordinated turn.

j) switching the altitude corrector on ("MK" button) and indication that the altitude corrector is on ("MK" green light).

All the elements are located on the panel. The potentiometers "R", "T" and "H" have no knobs, but their shafts have slots for a screwdriver.

To facilitate connection of the control panel, it is fitted with a plug connector attached to a cable harness, 300 mm. long.

The control panel wiring diagram is shown in Fig. 36.

The control panel weight is 1 kg.

A small indicator (case 40 mm. in dia.) is used for displaying the M.V.G. erection.

The indicator normally indicates bank angles. With the "PITCH" button pressed (the button is located at the indicator) the indicator displays pitch angles.

The indicator operates on a principle of a electro magnetic lagometer.

The indicator scale has marks indicating zero bank and $\pm 45^\circ$ - bank in both directions.

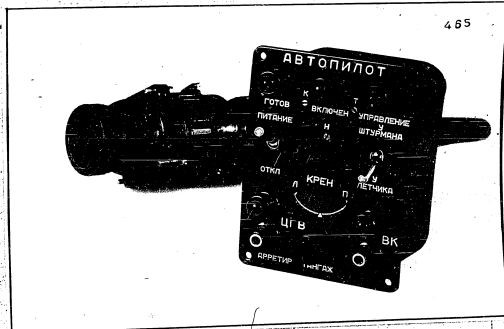


Fig. 37. Control Panel (General View)

Deflection of the pointer towards the mark "II" corresponds to the right bank or indicates diving with the "PITCH" button pressed.

Deflection of the pointer towards the mark "I" corresponds to the left bank or indicates climbing (positive pitch) with the "PITCH" button pressed.

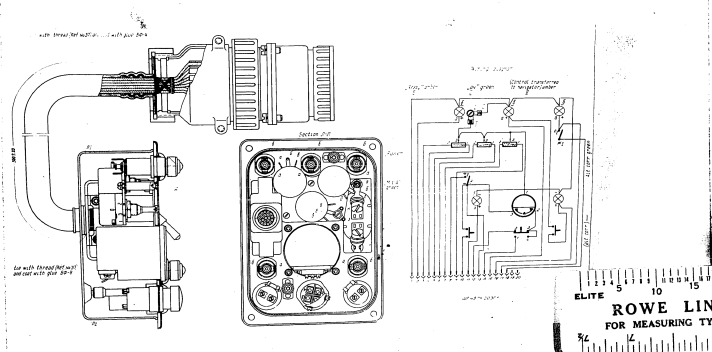


Fig. 38. Control Panel Design and Wiring Diagram

8. SERVO UNIT (PA-5BIII)

The PA-5BIII servo unit (Fig. 39) is a power actuating mechanism of the autopilot and is designed for moving the aircraft control surfaces. The servo unit is based on an electrohydraulic principle of operation. A signal from the autopilot is received by the servo unit electric system - the solenoid relay (6). The relay through the corresponding elements actuates the servo unit hydraulic system which moves the actuating rod (1) linked to a control surface via a levered system.

The servo unit consists of the casing (3), solenoid polarized relay (6), solenoid valve (9), slide valve (12) with needle (11), hydraulic booster (2) and two pressure reducing valves (10). Pressed in the servo unit casing are steel trunions⁽⁴⁾ to attach the unit to the aircraft structure.

On the side surface of the unit are the hydraulic fluid inlet and outlet connections⁽⁵⁾. The casing is provided with adjusting screws regulating the quantity of fluid passing to the return line and changing the jet opening.

Inside the unit casing are recesses to accommodate the unit assemblies and oil passages.

The polarized relay with the needle and the solenoid valve are enclosed by the duralumin cap (7) fitted with the pressure sealed cable (8) protected by a shield braiding.

Fig. 40 illustrates the servo unit schematic diagram.

An electric signal, received from the autopilot amplifiers, actuates the relay (7).

The relay armature (15), deflecting to either side depending on the signal sign, moves the needle (17) of the control valve (13) through the lever (16).

Following the needle, the control valve moves and unbalances the hydraulic forces affecting the slide valve ends.

The control valve, being a distributing device, permits the fluid under pressure to enter one of the chambers of the hydraulic booster (18) and communicates simultaneously the second chamber with the return line.

The fluid under pressure enters the servo unit hydraulic system through the inlet connection from the aircraft hydraulic system.

Passing through the filter (4) the fluid enters the reducing valve (3) which reduces the fluid pressure to 40 atm.

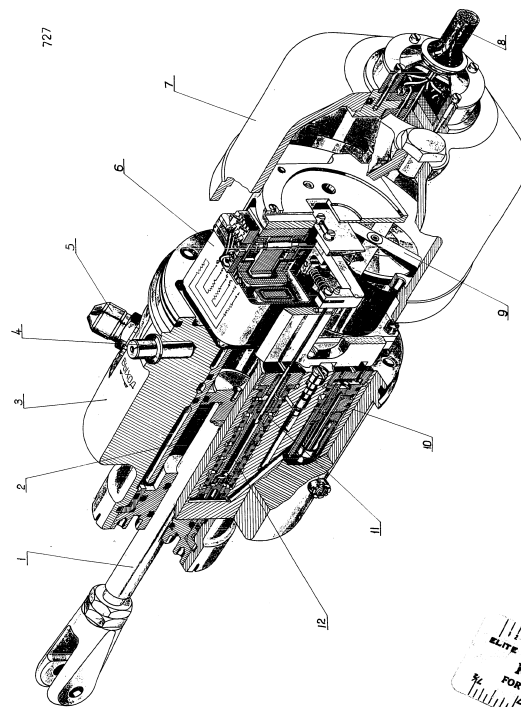


Fig. 29. Servo Unit



The pressure is regulated by tightening the reducing valve spring located on the outer side of the unit. In this case no disassembling of the unit is required. Then the fluid under a pressure of 40 atm. enters through the passages the groove between the centre shoulders of the control valve (10) slide valve and through the fine gauze filter (5) enters the reducing valve (6) which reduces the fluid pressure to approx. 2-3 atm.

Under this pressure the fluid through the passage enters the chamber "K" and through the jet enters the chamber "KH" of the control valve.

The jet opening regulation equalizes the speed of the actuating rod motion in either side when signals (equal in value but opposite in sign) are supplied to the relay. The jet opening is regulated by the throttle screw (8). With a signal received, the armature moves the lever with the needle to the right or to the left. In this case the section area of the needle grooves, passing the fluid from the chamber "KH" to the return line, is increased or decreased.

Due to this the pressure in the chamber "KH" changes, the force acting on the slide valve ends are unbalanced and the slide valve moves.

The direction of the slide valve movement coincides with that of the needle motion. With the slide valve moving, its centre shoulders close the barrel holes communicating with passages "A" and "B". It results in supplying fluid to one of the hydraulic booster chambers and evacuating fluid from the other chamber to the return line.

The adjusting screws (9) regulate the quantity of fluid entering the return line, thus decreasing and equalizing the actuating rod speed when retracting and extending.

Due to a pressure difference in the pressure and return chambers of the hydraulic booster, the actuating rod moves and actuates the aircraft control surface.

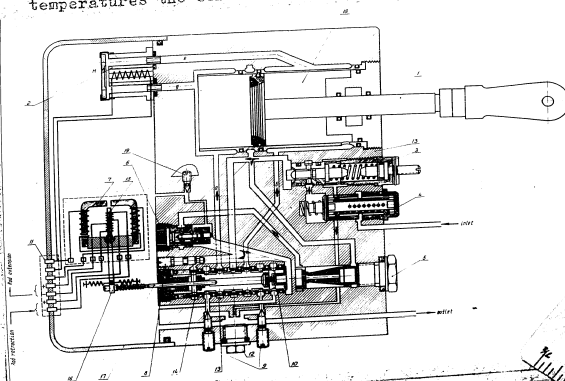
At the transfer to the manual control, the actuating rod should freely move in the barrel.

For this purpose, the servo units are fitted with the solenoid valve (2).

At the automatic control, the solenoid valve coil is energized, the armature is pulled up and the passages "e" and "H" are closed.

With the autopilot disengaged, the relay armature, under the springs action, will return to centre position, move the lever with the needle and the slide valve to neutral position. The slide valve shoulders close the barrel holes communicating with the passages "a" and "G" - the fluid is blocked. At this time the solenoid valve coil becomes de-energized and the spring lifts the cover "M". The hydraulic booster operating chambers communicate through the passages "e" and "H" permitting free movement of the actuating rod which is necessary for manual control.

To ensure normal operation of the servo unit at low and high temperatures the servo unit is heated or cooled by fluid flow.



ROWE
FOR MEASURING

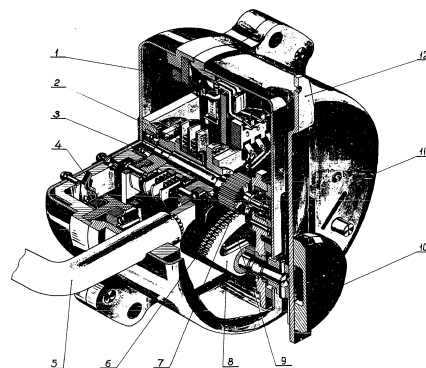


Fig. 41 Feed- Back Transmitter

The transmitter is linked to the control system so that the maximum operating angle of the transmitter would be used. The operating angles zone is marked on the housing (11) by red paint. The transmitter kinematics is corrected by changing the arm length of the lever (12) attached to the shaft by the plate (10).

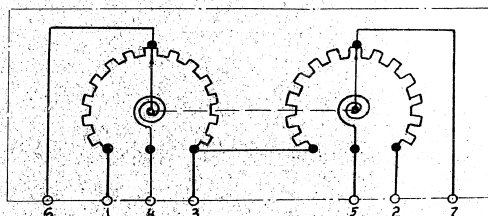


Fig. 42. Feed-Back Transmitter Wiring Schematic Diagram

TECHNICAL DATA (ROC-800A)

1. Supply voltage $\pm 27 \text{ V} \pm 10\%$
2. Range of lever deflection from centre position, within which a signal proportional to a deflection angle is sent $\pm 40^\circ$
3. Angle of lever deflection to stops $\pm 40-45^\circ$
4. Number of potentiometer winding turns per degree of lever deflection.. 12
5. Potentiometers are wound with constant enameled wire HSK, 0.12 mm. dia.
6. Each potentiometer resistance..... $720 \pm 100 \text{ ohms}$
7. Weight 0.4 kg.

10. VIBRATOR (B-847E)

The vibrator (Fig.43) is designed for elimination of the insensitivity zone in the autopilot drive system.

The vibrator supplies all the channels with a sinusoidal signal of about 3 c.p.s. which is summed up with the main signals and is sent to the control surfaces.

The control surfaces constantly vibrate about the position established by the main signals.

The aircraft responds only to the mean position of the control surfaces and does not respond to the control surfaces vibration about this mean position due to small amplitude and comparatively high frequency.

The sinusoidal signal is generated by the induction potentiometer (5).

When the induction potentiometer rotor turns 360° , the voltage, picked up from the signal winding, changes according to the sine law and passes six cycles. The induction potentiometer rotor shaft is connected to the motor (10) through the reduction gear (7). The frequency of the voltage picked up from the vibrator is changed by regulating the motor speed using the potentiometer "FREQUENCY".

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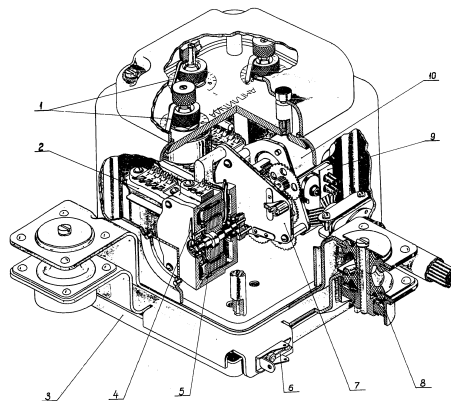


Fig. 43. Vibrator (B-847E)

The induction potentiometer signal winding voltage is supplied to the three transformers (2) windings (for each channel of the autopilot; then the signal is fed to the autopilot channels through the potentiometers (1) "X", "Y" and "Z" regulating the output voltage amplitude.

The output voltage frequency is determined by the speed of the pointer (4) rotation according to the formula:

$$f = \frac{6}{t} \frac{E}{\pi}$$

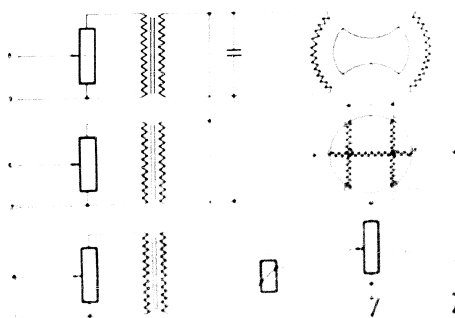
where: n - r.p.m.
 t - time in sec.

In the synchronizing mode, the vibrator is off. The vibrator is energized through the relay (2) when the button "ON" button is pressed.

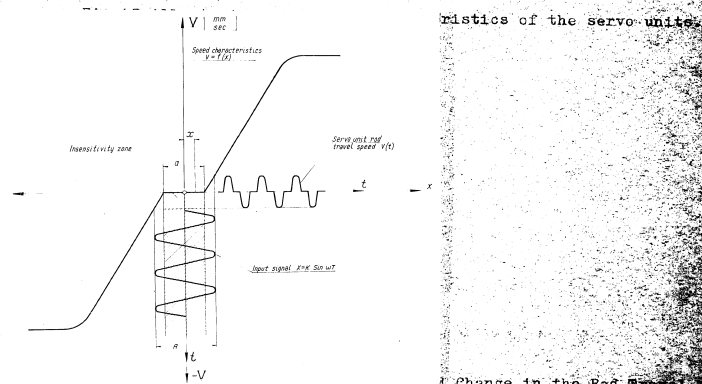
The vibrator is attached to the rigid case by the link-release latch (6).

The vibrator is installed on three pairs of the shock-mounts (3).

The arrangement of the shock-mounts in pairs reduces their stiffness which ensures reliable shock-absorbing at low frequency. To facilitate mounting of the vibrator it is provided with a plug-connector attached to a cable harness of 100 cm. long.



The improvement of the sensitivity of the system by the vibrator can be shown as follows:



Plotted on the "X" axis is the input signal "X" (current in the servo unit relay control windings); on the "Y" axis - the travel speed of the servo unit rod with the feed-back circuit open.

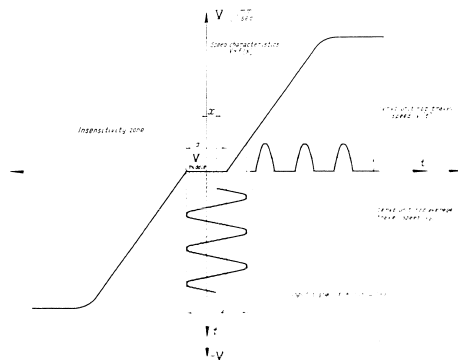
If the servo unit receives a constant input signal less than the sensitivity threshold, the servo unit rod remains motionless.

If the servo unit receives a sinusoidal input signal with an amplitude below the insensitivity zone, the servo unit rod will be motionless too.

If the servo unit receives a sinusoidal input signal with an amplitude exceeding the insensitivity zone, the servo unit rod will vibrate about zero position.

The rod travel speed will equal to zero.

If a constant signal (X), less than the sensitivity threshold, and a sinusoidal signal, with an amplitude exceeding the insensitivity zone are simultaneously received by the servo unit, the rod will move at an average speed V_{av} . (Fig.46).



Action of Constant and Sinusoidal Signals.

The rod travel speed will be about an average value V_{av} proportional to the constant input signal less than the insensitivity threshold. Thus the system sensitivity is improved.

TECHNICAL DATA (B-2472)

1. Frequency adjustment range of voltage picked off the vibrator
2. Range of input voltage amplitude adjustment (in channels):

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bank - 22 V, 400 c.p.s.

pitch - 22 V, 400 c.p.s.

direction - 8 V, 400 c.p.s.

3. Supply voltage:

A.C. - 36 V $\pm$ 2 V, 400 $\pm$ 8 c.p.s.

D.C. - 27 V $\pm$ 10%.

4. Weight 1.4 kg.

11. AUTOPILOT "ON" BUTTON (KHH)

The autopilot "ON" button (Fig.47) is used for engaging the autopilot. For this purpose a standard KHH button is used.

The button has two pairs of contacts: one pair is normally closed - with the button pressed; these contacts break the interlocking circuit preventing the autopilot to control the aircraft after returning to level flight; the other pair of normally-open contacts supplies voltage to the autopilot engaging relay.

The "ON" button is installed at the navigator's station.

Button weight - 0.02 kg.



Fig.47. Autopilot "ON" button.

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12. AUTOPILOT "OFF" BUTTON (Fig.48)

The autopilot "OFF" button (Fig.48) is used for disengaging the autopilot.

One button is installed on the pilot's control wheel, the other button at the navigator's station.

The "OFF" button opens the circuit.

The button is fitted with four contacting points to ensure its reliability of operation.

The button body is red coloured and painted with luminous material in the centre.

Button weight - 0.02 kg.

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Fig. 48. Autopilot "OFF" Button

13. "RETURN TO LEVEL FLIGHT" BUTTON

The "RETURN TO LEVEL FLIGHT" button (Fig.49) is used to switch the autopilot on for automatic returning of the aircraft to level flight position.

A 5K-C button is used for this purpose.

Button weight - 0.02 kg.



Fig. 49. "RETURN TO LEVEL FLIGHT" Button

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14. "RECOVERY FROM BANK" BUTTON (KHI)

The "RECOVERY FROM BANK" button is used to switch the autopilot on for automatic returning the aircraft to level flight position after a turn without changing an angle of pitch.

The "RECOVERY FROM BANK" button is similar in construction with the autopilot "ON" button (Fig.47).

P-27 Carbon-Pile Voltage Regulator

**DESCRIPTION, OPERATING AND MAINTENANCE
INSTRUCTIONS**

P-27 Carbon-Pile Voltage Regulator

DESCRIPTION, OPERATING AND MAINTENANCE
INSTRUCTIONS

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DESCRIPTION

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DESCRIPTION

I. PURPOSE

The carbon-pile voltage regulator, type P-27, is intended to:

(a) automatically maintain constant voltage on aircraft generators of ICP or FC series and starter-generators of ICP-CT series (rated at 3000 to 12,000 W) with field current within the range of 0.9 - 8 A;

(b) ensure even distribution of the load between paralleled generators of the same type.

The P-27 regulators are manufactured either with right- or with left-hand shock absorbing panel. The kind of the shock absorbing panel selected depends upon the installation and service requirements.

Till October 1956 P-27 regulators provided with right-hand panels were issued with index P-27 Hp and those provided with left-hand panels, with index P-27L. Since October 1956 regulators are issued with index P-27 irrespective of the kind of panels on which they are installed.

II. SPECIFICATIONS

A. Operating Conditions

1. The P-27 regulator normally operates and maintains the voltage of an aircraft generator within the preset range under the following conditions:

- (a) generator speed 4000 - 9000 r.p.m.
- (b) load 0 - 100 per cent
- (c) ambient temperature at
 ground level from -60 to +50°C
- (d) altitude above sea level

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- at ambient temperature -40°C and below
up to 17,000 m.
- (a) relative humidity of ambient air
up to 98 per cent
- (f) vibration frequency of fastening parts at
acceleration of 4 g 30 - 80 c.p.s.
2. The regulator ensures stable voltage during short-time operation (up to 2 hours) at an altitude to 16,000 m. and temperature of 0°C .
3. The regulator ensures stable voltage during short-time operation (5 min. during two-hour period outlined in Item 2) at an ambient air temperature of $+90^{\circ}\text{C}$ and altitude up to 11,000 m. and at a temperature $+40^{\circ}\text{C}$ and altitude up to 20,000 m.
4. The regulator withstands a short-time jolting with frequency from 40 to 100 impacts per minute at acceleration up to 4 g.

B. Basic Specifications

1. Rated voltage maintained by the regulator is 28.5 V.
2. Voltage maintained by the regulator operating in conjunction with the generator under conditions outlined in Items "a" and "b" of Section A, at an ambient temperature of $+20^{\circ}\text{C}$ and a preset position of the BC-25B rheostat slide must be within the limits of 27 - 29.7 V (± 0.2 V).
3. Variations in the voltage maintained by the regulator operating in conjunction with the generator under conditions outlined in Item 1 of Section A must not exceed 3.5 V. When taking into account the operating conditions outlined in Items 2 and 3 of Section A, the variation must be not more than 4 V. At the same time the generator voltage with the BC-25B rheostat slide in the preset position must not exceed 30 V.

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4. The BC-25B rheostat ensures voltage variations within the following ranges:
 - (a) increase of voltage by 1 V and decrease by 3.5 V when the regulator operates with a T-11' transformer;
 - (b) increase of voltage by 2 V and decrease by 2.5 V when the regulator operates with a transformer of TC-9 series.
5. Regulator operating duty - continuous.
6. The maximum power dissipated in the carbon pile is 85 W.
7. The regulator is provided with a MPP-9 carbon pile having the following parameters:
 - (a) resistance in heated state at a pressure of 5 gr not less than 41 ohms
 - (b) resistance in cold state at a pressure of 5 kg not more than 0.36 ohm
 - (c) deformation of the carbon pile at a pressure changing from 5 gr to 5 kg not more than 0.38 mm.
8. For winding data of the P-27 regulator and its elements, see relevant table.
9. Total weight of the regulator (complete with a BC-25B rheostat and terminal block) is 1.75 kg.
10. The regulator operates in conjunction with a TC-9A (TC-9AM) or TC-9A-12 (TC-9AM-12) transformer depending upon the generator output.

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P-27 Regulator Winding Data

Type of winding and resistor	Designation in diagram	Wire dia. w/o insulation, mm	Wire mark	Number of turns	Resistance at +20°C, ohms
I. Regulator					
1. Operating winding	1 ₁	0.59	ПЗБ-2	600	3.8 ± 0.3
2. Temperature compensating winding	1 ₂	0.09	ПЗМ	4000	1640 ± 130
3. Equalizing winding	S ₀	0.74	ПЗБ-2	62	0.35 ± 0.03
II. BC-25B Rheostat		0.4	ПЗК		6 ± 0.3
III. Temperature compensating resistor ПЗБ-25-20	R ₁				20 ± 1
IV. Stabilizing resistor ПЗБ-10-1500	R ₂				1500 ± 150

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If the regulator operates in the circuit without storage batteries, it is allowed to use a T-1I' transformer instead of the transformers indicated above. The regulator set does not include transformers. Operation of the P-27 regulator without a stabilizing transformer is not guaranteed.

III. DELIVERY LIST

The P-27 regulator set (Fig. 1) includes:
 (a) regulator proper 1 with BC-25B rheostat and shock absorbing panel 2 (right- and left-hand);
 (b) certificate (filled in and signed);
 (c) type КЕМ-31, 4 μF capacitor 3;
 (d) description and Repair Manual.

IV. DESIGN AND PRINCIPLE OF OPERATION

A. Simplified Carbon-Pile Regulator

The carbon-pile regulator consists of two main elements:

- (a) electromagnet with armature reacting to changes of regulated voltage;
- (b) carbon pile serving in the regulator as a variable resistor.

A diagram of the simplified voltage regulator is given in Fig. 2.

The regulator electromagnet is made with an air gap. Regulator operating winding 1 is arranged inside electromagnet case 3. The electromagnet case is a hollow cylinder with the bottom closed by cover 4 to which thread core 2 is attached. Turning of the core in the cover makes it possible to change air gap δ between its face and armature 5.

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The core projects through the hole made at the centre of the electromagnet case bottom. Duralumin ring 6 against which the armature rests through flat springs 7 fits to the electromagnet bottom. The case with the cover and bottom, core and armature serve as a magnetic conductor of the electromagnet. Magnetic flux created by the operating winding is closed through the core, cover, cylindrical part of the case and its bottom, electromagnet armature and again to the core. Insignificant part of the flux is closed directly from the bottom to the core (passing by the armature).

One end of carbon pile 9 rests against armature carbon contact 8 while the other end is in touch with second carbon contact 12 arranged on the face of adjusting screw 13 fitted into the flange of finned cooler 10. Both carbon contacts are electrically isolated from the finned cooler and armature.

The carbon pile consisting of a number of thin carbon discs is enclosed in insulating tube 11 secured in finned cooler 10. The fins provide large cooling surface. The electromagnet case and the carbon pile finned cooler are connected by means of steel studs 18.

Thus, the carbon pile of the regulator is clamped between the contacts of the adjusting screw and armature. When the adjusting screw is turned into the flange, the carbon pile is compressed and subjected to the pressure exerted by the armature springs. Depending upon the strength of pressure the carbon pile electrical resistance changes: the more is the pressure upon the carbon pile the less is its resistance.

Electromagnet winding 1 is connected to generator terminals 16 through temperature compensating resistor 14 and adjustable resistor 15. The regulator carbon pile is connected in series with generator field winding 17. If the generator voltage varies, the strength of the armature

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attraction to the regulator electromagnet changes correspondingly and this results in shifting of the armature.

Shifting of the armature changes pressure upon the carbon pile and consequently changes its resistance. This in turn changes the generator field current due to which the voltage tends to approximate the initial level.

The regulator armature is acted upon by three forces:

- (a) electromagnet pull, $P_{el.m.}$;
- (b) carbon pile resilience, P_{carb} ;
- (c) counteracting force of armature spring, P_{spring} .

The electromagnet pull and the carbon pile resilience are acting in the same direction while the armature spring force acts in the opposite direction.

$$P_{el.m.} + P_{carb} = P_{spring}$$

Each of the forces acting upon the armature depends on the armature shifting, i.e., on the air gap between the armature and the electromagnet core. Variations of the forces caused by changing of the air gap are given in Fig. 3.

If the generator voltage is zero, the electromagnet creates no pull and forces of the spring and carbon pile resilience are equal. In this case the armature springs are compressed to a minimum. For the P-27 regulator the compression effort is about 5 kg.

The above mentioned effort is the maximum effort exerted upon the carbon pile in the regulator; at the same time the carbon pile resistance is minimum (0.3 - 0.4 ohm).

Increase of the generator voltage intensifies the pull of the regulator electromagnet due to which pressure upon the carbon pile is simultaneously reduced and its re-

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sistance increased. An increase of voltage from 0 to 25 - 26 V changes the carbon pile resistance insignificantly, but further rise of voltage causes sharp increase of the pile resistance.

When the voltage reaches its rated value (at this moment the regulator starts functioning as a regulator) the carbon pile offers a resistance which is 5 times greater than the initial (when the electromagnet winding is deenergized). For the P-27 regulator this resistance is equal to approximately 1.5 - 2 ohms which is the lower limit of the carbon pile resistance operating range and which must be taken into account when calculating generators (to make a reserve and to increase the accuracy of adjustment it is recommended to make calculations proceeding from somewhat greater value of the carbon pile minimum resistance).

If the lower limit of the resistance operating range is defined mainly by the regulator parameters, the upper limit depends on the value of the resistance necessary for maintaining rated generator voltage at maximum and idle speeds.

For generators operating with P-27 regulators the maximum required resistance amounts to 28 ohms. To ensure the reliable operation of the regulator for a continuous time the carbon pile resistance must considerably surpass this value (approximately by 1.5 times).

During the steady-state operation of the regulator the forces acting upon the regulator armature are balanced (their sum is equal to zero). The armature is motionless and assumes quite a definite position at which it compresses the carbon pile with an effort necessary for ensuring a certain resistance according to the given value of the generator voltage.

When the operating conditions of the generator are changing (change of speed or load), first it causes change

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of the generator voltage resulting in disturbance of the equilibrium of forces acting upon the armature and the latter starts to shift until a new equilibrium of forces is achieved.

The regulator armature will assume a new position and the carbon pile resistance will vary (as a result of the change of pressure exerted upon it) so as to restore the given level of the generator voltage.

The simplified carbon-pile voltage regulator is practically able to ensure only static adjustment and therefore it brings the generator voltage not to the initial value as is the case with astatic adjustment, but to a value somewhat differing from the initial.

The astatic adjustment is possible only in case the regulator electromagnetic and mechanical characteristics precisely coincide within the operating range of the gaps. The mechanical characteristic is a difference of the armature springs effort and the carbon pile resilience. However, such a coincidence of the characteristics is practically unachievable, as a rule they intersect at a small angle; moreover, it is impossible to reduce to zero the magnetic hysteresis of the electromagnet, mechanical hysteresis of the carbon pile and the armature springs, friction of springs and other factors introducing errors into adjustment.

All this leads to a certain difference between the electromagnetic and mechanical characteristics and stipulates the static character of the generator voltage adjustment. The most vivid example for analyzing the generator operation is given by the characteristics presented in Fig. 3.

Let point A of intersection of electromagnetic and mechanical characteristics correspond to a steady-state operation at a voltage of 28.5 V at which the gap between the armature and core is equal to δ_1 .

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Let us assume that due to a drop of load the generator voltage instantly rises up to 30 V. Since the armature due to lagging (inertia) of the system remains motionless at the first moment the electromagnetic pull acting upon the armature at the same gap δ_1 will rise with increase of voltage to a value corresponding to point B in the diagram.

With increase of the electromagnetic pull, the equilibrium of the forces acting upon the armature is upset and the armature will shift towards the electromagnet thus reducing the air gap. In this case the pressure exerted upon the carbon pile decreases which leads to increase of its resistance and consequently to reduction of the generator voltage.

As the armature shifts the forces acting upon it change. The electromagnetic pull exceeding the mechanical force at point B is slightly decreased due to change of the generator voltage (as compared with the electromagnetic pull corresponding to point A, the electromagnet pull when the armature shifts is higher due to decrease of the air gap). As the air gap decreases the mechanical force rises due to increase of the armature springs tension.

The armature will shift until at point B a new equilibrium of forces acting upon it is achieved. Point B is characterized by smaller air gap δ_2 , increased electromagnetic pull as compared with point A, and correspondingly increased tension of the springs.

A new equilibrium of forces will take place at a voltage level somewhat different from the initial, for instance, for point B it equals 29 V. The difference in the voltage levels is lesser the more accurate is coincidence of the regulator mechanical characteristic with one of the electromagnetic characteristics corresponding to a given voltage.

If due to any cause (increase of load, fall of generator speed) the voltage decreases, the process of regulation will take place in the reverse order. The voltage decrease

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causes reduction of the electromagnetic pull which upsets the equilibrium of forces acting upon the armature and the latter forced by the springs begins to shift towards increasing the air gap.

At the same moment the pressure exerted upon the carbon pile increases and its resistance decreases due to which the generator voltage rises. The electromagnetic pull is again intensified and at a certain point a new equilibrium of forces is achieved and the armature stops in the position characterized by a larger air gap and somewhat lesser pull of the electromagnet and springs.

Quite a definite position of the armature, i.e. a definite air gap corresponds to each operating condition of the generator depending upon the required carbon pile resistance. The extreme operating gaps are characterized by those positions of the armature at which the carbon pile develops the minimum required resistance (at minimum generator speed and rated load) and maximum resistance (at maximum generator speed without load). Variations of the carbon pile resistance within the above-mentioned limits is followed by a certain deformation of the pile. For instance, deformation of the MP-9 carbon pile used in P-27 regulators at extreme required resistances is approximately 0.15 mm. Therefore, the operating range of the gaps must somewhat exceed this value.

It is precisely the range within which the best coincidence of the regulator mechanical characteristic and electromagnetic characteristic corresponding to the rated value of the regulated voltage must be ensured. Such a coincidence is the most probable the less is the operating range of the gaps which shows the necessity to obtain minimum value of the carbon pile deformation.

It is known that at a constant voltage (i.e. at constant current intensity or constant ampere-turns of the electromagnet), the electromagnetic pull changes non-lin-

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early with reduction of the air gap (approximately by the square-law). To obtain the variation of the armature springs tension of the same character a special ring with an inner cone against which the springs rest is used in the regulator. When the armature shifts, the bearing points of the springs on the ring conical surface are displaced which results in changing of the spring working length. Due to this it is possible to obtain a non-linear characteristic of the armature springs, close to the electromagnetic characteristic of the regulator.

With changing of the ambient temperature and heating of the regulator itself, a considerable variation of the finned cooler linear dimensions takes place, which causes a corresponding variation of the pressure exerted upon the carbon pile and leads to a considerable changing of the regulated voltage level. To limit such a phenomenon the regulator finned cooler is coupled with shaped bracket 19 (Fig. 2) by means of steel studs 18. The studs are attached to the first fin of the cooler while the opposite end of the cooler is free to move. Therefore, elongation of the cooler caused by heating moves it along the regulator axis without affecting the carbon pile and armature. These elements are affected only by changing of the steel studs length which is not great since the steel factor of expansion is small.

B. Design of P-27 Regulator

The design of P-27 voltage regulator is similar to that of a widely used P-25AM regulator. To ensure more reliable operation of the regulator at greater altitudes and higher temperatures its design has the following peculiarities.

1. To enlarge the cooling surface the outer diameter and length of the finned cooler are increased which

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permitted to increase the number of fins. Outer diameter of the P-27 regulator finned cooler is 82 mm, its length - 58 mm and number of pins - 10, while diameter and length of a P-25AM regulator finned cooler are 74 and 50 mm respectively and number of fins is 9.

2. The P-27 regulator carbon pile is placed into a duralumin tube with oxide-varnish insulating coating, pressed into the finned cooler. A similar tube was earlier used in a PVT-82 regulator. As compared to the ceramic insulating tube used in P-25AM regulators the duralumin tube has a high heat conduction which ensures better heat removal from the carbon pile. As the oxide-varnish insulating coating of the metal tube is calculated for a voltage of 200 V D.C. (which is quite sufficient for the regulator of the given designation) and taking into account the possibility of checking the circuit or measuring the insulation resistance by a 500-V megger, the finned cooler is insulated from the regulator body by means of insulating bushings and washers installed at places of fastening. This additional insulation prevents casual puncture of the tube.

3. A new MFP-9 carbon pile is used in the P-27 regulator. As distinguished from the MFP-1A (MFP-1M) MFP-1A carbon piles used in P-25A and P-25AM regulator the MFP-9 carbon pile is 57 mm long and made of a half-finished product GT-8 and ensures higher maximum resistance.

Resistance of the MFP-9 carbon pile at a pressure of 5 kg is not more than 0.36 ohm when cold, and after 30 min. heating at 60 W it is not less than 41 ohms (at a pressure of 5 gr). Deformation of the pile with changing of pressure from 5 gr to 5 kg must not exceed 0.38 mm.

According to the Specifications for a MFP-1A carbon pile its resistance amounting to 30 ohms at a pressure of 5 gr was guaranteed only for a cold state. In hot state

its resistance was not guaranteed by the specifications and the actual value of the pile resistance at a pressure of 5 gr was 20 - 28 ohms (which is approximately two times less than that of the MP-9 pile).

The MP-9 carbon pile having higher maximum resistance and greater length is inferior as compared with the MP-1A pile in minimum resistance and value of deformation. This leads to a certain deterioration of regulation accuracy. However, the two-fold increase of the maximum resistance ensures reliability and endurance of the MP-9 carbon pile during continuous operation of the P-27 regulator at great altitudes and small loads of FCP-CT-6000A generators which could not be ensured in a P-25AM regulator with a MP-1A carbon pile.

4. The armature with petal springs in assembly with the conical distance ring is used in the P-27 regulator. The similar system is used in P-25A regulators while the P-25 AM regulator armature has a spring of a diaphragm type.

The petal armature as compared with the diaphragm armature ensures better stability of the regulator and makes it possible to reduce the generator minimum speed at which the latter operating in conjunction with the regulator is able to develop rated voltage.

5. The P-27 regulator plate, arrangement and fastening of the circuit elements on it differ from those of the P-25AM regulator.

6. The P-27 regulator panel is not interchangeable with that of the P-25AM regulator which is reasoned by the necessity to preserve the former mounting for installing the P-27 regulators on one of the series aircraft. Earlier the regulators installed on these aircraft at the left side of the fuselage were turned through 180° relative to the regulators at the right side which caused an additional unbalance of voltages and load cur-

rents of generators under influence of linear accelerations.

Installation of the P-27 regulators on the above-mentioned aircraft both in the left and right wings is similar and only the necessity to preserve the mounting required construction of two different panels (left and right).

To facilitate installation of the regulator proper on the panel or its removal the hinged-type panel locks are used. The windings and electric circuit of the P-27 regulator are identical to those of the P-25A regulator.

C. P-27 Regulator Electric Circuit

The P-27 voltage regulator electric circuit greatly differs from the circuit of the simplified carbon-pile regulator given in Fig. 2. To increase the accuracy of regulation and stability of the regulator and to ensure the operation of several generators in parallel the circuit is provided with a number of additional elements. The key diagram of the P-27 regulator is given in Fig. 4.

Beside operating winding l_1 the electromagnet coil is provided with temperature compensating winding l_2 and paralleling winding S_0 .

Operating winding l_1 creates the main magnetic flux of the regulator electromagnet. It is connected to the generator terminals through constantan resistor R_1 and adjustable resistor R (low-resistance winding l'_1 of the stabilizing transformer is cut in series with the same circuit). Resistor R_1 made of constantan does not practically change its value and is introduced into the circuit for temperature compensation, since the variation of the operating winding resistance caused by changing of the ambient temperature from -60 to +30°C and heating of the regulator itself would have led to a considerable depend-

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ence of the regulated voltage on the temperature and to an inadmissible reduction of the regulation accuracy.

Resistance of operating winding l_1 made of copper is approximately 4 ohms and constantan resistor R_1 together with adjustable resistor R (also made of constantan) equals approximately 24 ohms which gives the ratio of copper and constantan resistors as 1:6. This considerably reduces dependence of the total resistance of the entire circuit and consequently the value of the regulated voltage on the temperature.

However, such a temperature compensation is not sufficient and, if additional measures are not taken, the voltage variation at great temperature fluctuations will remain considerable. For instance, when the operating winding of the regulator is heated to approximately 80°C , then at the temperature compensation given above, the difference of the regulator voltage levels at the ambient temperature of -60°C in a cold state and at a temperature of $+50^\circ\text{C}$ in a heated state will be equal to about 3 V (which is too great).

Therefore, to ensure more complete temperature compensation the P-27 regulator is provided with special compensating winding l_2 . The magnetic flux of this winding is approximately 10 per cent of the magnetic flux of the operating winding and is directed towards it. The compensating winding is cut directly (without a constantan resistor) into the generator voltage; its resistance changes proportionally to the temperature and according to this current and ampere-turns of this winding vary.

Parameters of the compensating winding are selected so as to compensate for reduction or increase of the operating winding magnetic flux (ampere-turns) with changing of the ambient temperature and heating of the regulator itself. Then the resulting magnetic flux of both windings (equal to the difference of the fluxes of the operating

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and compensating windings) despite the temperature variation will remain approximately constant. Due to this the influence of the ambient temperature and heating of the regulator operating winding on the regulated voltage level is insignificant. For instance, with the ambient temperature changing from -60 to $+50^\circ\text{C}$ and with due regard for the P-27 regulator heating, the voltage level variation does not exceed 0.5 V.

It should be mentioned that here we consider only the electric compensation related to variations of the windings resistance. Besides, with variations of the temperature the length of the carbon pile, studs and, consequently, operating gaps are changed which also leads to changing of the regulated voltage level and, therefore, it is taken into in the regulator design.

Regulator paralleling winding S_0 serves for automatic equalizing of load currents of generators when they operate in parallel. Equalizing of load currents of the generators operating in parallel is achieved by influence of these windings upon the value of the regulated voltage.

As shown in diagram presented in Fig. 5 the load of the generators is checked by the voltage drop across the ballast resistors cut into the negative circuits of the generators. The above-mentioned voltage drop is proportional to the load current of the generators.

At equal loads of the generators voltage drops in the ballast resistors are equal. Consequently, the potentials at points a_1 and a_2 (points at which the equalizing windings of the regulators are cut in) are equal, the circuit of these windings is de-energized and the windings do not affect the level of the regulated voltage.

Unequal loads on the generators produce different voltage drops across the ballast resistors. Therefore,

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the potentials at points a_1 and a_2 become unequal, current appears in the circuit of the regulator equalizing windings inducing additional magnetic fluxes in the electromagnets of the regulators, which are added to, or subtracted from, the magnetic flux of the regulator operating windings. Accordingly this leads to voltage variation of the generators toward levelling of their loads.

Let us suppose that the load of the first generator shown in the diagram in Fig. 5 exceeds that of the second generator. In this case, voltage drop across ballast resistor R_3 of the first generator will exceed that across ballast resistor R_4 of the second generator. The potential at point a_2 will be higher than that at point a_1 and, therefore, current will flow from point a_2 to point a_1 through the equalizing windings of the regulators inducing an additional magnetic flux in the first regulator directed in the same way with the operating winding magnetic flux and in the second regulator - in the opposite direction. Under the action of the regulators this will lead to reduction of the first regulator voltage and to increase of the second regulator voltage due to which the load currents of both generators will be levelled. The same process will take place when three or more generators operate in parallel.

Thus, the equalizing windings of the regulators level the load currents of generators operating in parallel by affecting the level of the regulated voltage.

D. Stabilizing Devices

The circuit of the generator voltage regulation consists of several elements presenting a closed system: generator - generator operating winding - carbon pile - field winding - generator. Such a successive system of

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elements causes a considerable lagging in regulation due to which changing of the carbon pile resistance and the generator field current cannot take place instantly.

The regulator lagging leads to such a condition at which the regulator after a sharp changing of the generator operating conditions is not able to maintain constant voltage during the transient period, which prolongs the transient process and may cause voltage fluctuations.

At the first moment after the load drop the generator voltage sharply increases (due to lagging of the regulation system). The electromagnetic pull increases and shifts the armature towards the electromagnet core which diminishes the pressure exerted upon the carbon pile, which in turn increases the carbon pile resistance and correspondingly reduces the generator voltage. Due to its inertia the regulator reduces the voltage to a greater degree than is necessary for obtaining the required level, which leads to a superfluous reduction of the electromagnetic pull and reverse regulation, i.e. regulation towards voltage increase. Due to lagging the regulation of voltage above the given level will take place and the following cycle of regulation will be repeated.

Thus, voltage fluctuations which in a stable system should quickly damp appear during the transient period. However, when damping of the system is insufficient or adjustment of the regulator is not correct, the fluctuations may become undamped.

To facilitate the damping of fluctuations separate regulating elements are provided with a feedback. One can distinguish a direct feedback affecting the regulator both during the transient and steady-state conditions and a transient feedback acting only at transient conditions.

To increase the stability the P-27 carbon-pile regulator is provided with both kinds of feedback.

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the potentials at points a_1 and a_2 become unequal, current appears in the circuit of the regulator equalizing windings inducing additional magnetic fluxes in the electromagnets of the regulators, which are added to, or subtracted from, the magnetic flux of the regulator operating windings. Accordingly this leads to voltage variation of the generators toward levelling of their loads.

Let us suppose that the load of the first generator shown in the diagram in Fig. 5 exceeds that of the second generator. In this case, voltage drop across ballast resistor R_1 of the first generator will exceed that across ballast resistor R_2 of the second generator. Potential at point a_2 will be higher than that at point a_1 , and, therefore, current will flow from point a_2 through the equalizing windings of the regulator, inducing an additional magnetic flux in the first generator winding in the same way with the operating winding flux and in the second regulator - in the opposite direction. Under the action of the regulators there will be a reduction of the first regulator voltage and an increase of the second regulator voltage due to which the load currents of both generators will be levelled. This process will take place when three or more generators operate in parallel.

The equalizing windings of the regulators induce the currents of generators operating in parallel and level the level of the regulated voltage.

1. Stabilizing device

The system of generator voltage regulation consists of several elements presenting a closed system: generator - generator operating winding - carbon pile - equalizing winding - generator. Such a successive system of

elements causes a considerable lagging in regulation due to which changing of the carbon pile resistance and the generator field current cannot take place instantly.

The regulator lagging leads to such a condition at which the regulator after a sharp changing of the generator operating conditions is not able to maintain constant voltage during the transient period, which prolongs the transient process and may cause voltage fluctuations.

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Thus, voltage fluctuations which in a stable system should quickly damp appear during the transient periods. However, when damping of the system is insufficient or adjustment of the regulator is not correct, the fluctuations may become undamped.

To facilitate the damping of fluctuations separate regulating elements are provided with a feedback. One can distinguish a direct feedback affecting the regulator both during the transient and steady-state conditions, and a transient feedback acting only at transient conditions.

To increase the stability the K-27 carbon-pile regulator is provided with both kinds of feedback.

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The direct feedback is effected by resistor R_2 which is connected, as shown in Fig. 6, into the diagonal of the bridge, two arms of which are composed by the generator field winding and the carbon pile. The third arm includes temperature compensating resistor R_1 ; the fourth arm includes regulator operating winding l_1 , adjustable resistor R (rheostat BC-25B) and low-resistance winding l_1' of the stabilizing transformer. The second diagonal of the bridge is fed by the generator voltage.

The bridge is balanced only for one particular operating condition of the generator and, therefore, current flows through stabilizing resistor R_2 its value and direction being determined by the difference of potentials at points A and C. With an invariable voltage of the generator the potential at point C is constant while the potential at point A is a variable value and depends on the generator operating conditions.

During variations the variation of current flowing through the stabilizing resistor stipulates the alteration of the voltage drop across resistor R_1 which provides for damping of the voltage fluctuations.

The principle of the stabilizing resistor operation is as follows. Suppose that a load is dropped during the operation of the generator. At the first moment the voltage will sharply rise, since due to the regulator inertia the carbon pile resistance at this moment will remain unchanged and the current flowing through the stabilizing resistor will remain also constant since the potentials at points A and C change proportionally.

However, when the carbon pile resistance and resistance of the generator voltage will take place, with increasing of the carbon pile resistance the voltage drop across it will increase and the potential at point A will decrease, while the difference of potentials at points C and A will rise. This will lead to an increase of the current

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flowing through the stabilizing resistor. The latter in turn will induce an increase of the voltage drop across temperature compensating resistor R_1 and will lead to reduction of voltage across electromagnet winding R_1 which reduces the re-regulation of voltage (i.e. reduction or increase of voltage against the required level) and facilitates damping of the voltage fluctuations at transient conditions.

During the steady-state operation of the generator the variation of the current flowing through the stabilizing resistor and depending upon the carbon pile resistance leads to a certain undesirable alteration of the regulated voltage level: increase of voltage with rise of the carbon pile resistance and reduction of voltage with fall of the pile resistance. Thus, the stabilizing resistor makes the accuracy of regulation somewhat worse. However, increase of the regulated voltage acceleration due to the stabilizing resistor is approximately 0.3 - 0.4 V for a P-27 regulator which is inessential.

The transient feedback of the P-27 regulator is carried out by the stabilizing transformer which essentially adds up to stability of the regulator operation during transients and does not affect the level of the regulated voltage at steady-state conditions. The stabilizing transformer is connected into the common circuit of the regulator and generator but constructionally it is quite a separate unit.

Depending upon the operating conditions the P-27 regulator is used in conjunction with a shunt transformer T-11' or with a series transformer PC-9A, PC-9Am (or with the like transformer).

The T-11' transformer has two windings: primary, high-resistance winding l_2 and secondary, low-resistance winding l_1' . The primary winding is connected in parallel with the generator field winding and the secondary winding l_1' in series with the regulator operating winding.

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The TC-9A transformer besides the two above-mentioned windings is provided with series winding l_1' through which the generator load current runs and winding l_2' connected into the circuit of the regulator equalizing winding. Such type of transformers and their operation are described in Appendix 2.

Given below is the operating principle of stabilizing transformer T-1T.

The connection diagram of the T-1T stabilizing transformer is presented in Fig. 7. The current in transformer primary l_2 is determined by its ohmic resistance and voltage drop across the generator field winding. The current in transformer secondary l_1 is equal to a primary current I operating l_1 and compensating l_2 winding of the regulator.

This current creates a constant voltage drop insignificant in value across transformer secondary winding l_1 . Since resistance of this winding is small (~ 0.5 ohm), magnetic fluxes created in the transformer core by the direct component of current in the primary and secondary windings are opposite in direction.

If a sharp drop or sharp change in the generator load current is followed by the generator voltage fluctuations and consequently by fluctuations of the field current. Changes of the current induce a considerable electromotive force (e.m.f.) of self-induction in the field winding, the value of which can substantially exceed the value of the delivered current.

It will lead to fluctuations the alternating current induced in the field winding self-induction e.m.f. will flow through the transformer primary along with the direct component of current. Under the influence of this current an electromotive force will be induced in the transformer secondary. The e.m.f. adds up to the voltage drop in

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this winding, determined by currents of the regulator electromagnet coil or subtracts from it.

At an increased voltage of the generator when the regulator tending to reduce the voltage will intensify the carbon pile resistance and decrease the generator field current, the electromotive force induced in the transformer secondary adds up to the voltage drop in this winding. This is tantamount to the condition as if the regulator operating winding is supplied with a somewhat less voltage than the actual voltage of the generator is at that moment. As a result the possibility of the voltage re-regulation, that is its decrease below the given (for the steady-state operation) level is limited.

At a decreased voltage of the generator when the regulator will reduce the carbon pile resistance and increase the field current, the electromotive force induced in the transformer secondary subtracts from the voltage drop in this winding caused by the current in the regulator operating winding. Then the operating winding is under a somewhat greater voltage as compared to the actual instantaneous value of the generator voltage, which limits re-regulation of the voltage towards its increase.

Thus, at fluctuations of the regulated voltage pulses directed for damping of arising fluctuations are induced in the transformer low-resistance winding.

A series transformer TC-9A (and the like) is used for the purposes similar to those of the T-1T transformer. Besides it ensures more effective stabilization of the system due to existence of two more windings.

Series winding l_1' of the TC-9A transformer reacting to changes of the generator load current also induces in transformer secondary winding l_2' the electromotive force adding to damping of the generator voltage fluctu-

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ations. Operation of the series winding at fluctuations of the generator current is extremely effective.

At the same time the most intensive fluctuations of the generator currents are registered when it operates in conjunction with a storage battery or when several generators operate in parallel, since in this case voltage fluctuations of the generators at transients are accompanied by intensive fluctuations of the load caused by circulating currents between the generators themselves and between the generators and the storage battery. Therefore, in the above-mentioned cases it is necessary to use series transformers.

Operation of the series stabilizing transformer in the single generator circuit without a storage battery is approximately similar to that of the T-1I transformer. The only difference is that at the first moment when the generator load is dropped or switched on, influence of the series winding is manifest but lately it either disappears completely (load dropped to zero) or exerts no influence because of weak fluctuations of the generator current (load switched on).

E. Remaining Elements of the Circuit

The P-27 regulator circuit is provided with an adjustable resistor BC-25B (rheostat) used for adjustment of voltage which can slightly vary during a continuous period of operation due to wear of the carbon pile and permanent set of the armature springs. Adjustment of the voltage level is also necessary when adjusting parallel operation of generators for equalizing their currents. The resistor is made as a slide rheostat BC-25B installed on the regulator. When necessary the BC-25B rheostat can be removed from the regulator and installed at a place convenient for its usage (See Section VII).

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To eliminate radio interference arising during operation of the carbon-pile voltage regulator a ground capacitor is connected into its circuit. Used with the P-27 regulator is usually a 4 μ F capacitor of KBM-31 type (Fig.5).

The capacitor is installed separately from the regulator and connected to terminal E of the regulator panel. It should be mentioned that the wires connecting the capacitor leads to panel terminal E and the aircraft body must be as short as possible otherwise, the effectiveness of the capacitor will be considerably reduced due to induction of the wires themselves. When the wires are too long the action of the capacitor will be practically annulled.

V. SOME QUESTIONS ON STABILITY OF THE SYSTEM WITH PARALLEL OPERATION OF AIRCRAFT GENERATORS

Cases of unstable operation of the electric supply systems of some aircraft were registered during the last years.

Undamped fluctuations of voltages and load currents of the paralleled generators and storage batteries were noted at certain operating conditions, which caused disturbances in the normal operation of separate elements of the system. For instance, it caused excessive wear of generator brushes, contacts of minimum relays and carbon piles of voltage regulators.

Laboratory tests and investigations on the generators parallelly operating in the circuits similar to those of the aircraft confirmed in a number of cases the possibility of arising of self-oscillations in the system. Character of such oscillations is presented in Fig.8 where currents of two TGP-CT-6000A generators, one 12-CAM-28 storage battery and voltage across the load terminals are shown.

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It can be seen from Fig. 8 that at section I where load currents of the generators are low and at section II where load is substantially higher the system operates under stable conditions.

At section III after a sharp decrease of load (performed at the moment corresponding to point A), the system starts to operate under unstable conditions. At this section a constant variation of generators voltages directed into opposite directions takes place (voltage of one generator decreases and that of the other increases, then vice versa), which leads to a corresponding continuous redistribution of currents between both generators and the storage battery.

At the same time, the generators depending upon the value of total load in the mains can operate as electric motors. As a result, the generator is automatically disconnected from the mains as the back current reaches sufficient value and then is cut into the mains by differential minimum relays provided in the circuit. For instance, points E, B and F denote disconnection of generator No. 1 from the mains while points E', B' and F' show its cutting into the mains.

When load in the mains increases self-oscillations are stopped and the system becomes stable which is shown at section IV.

Investigations confirmed that arising of self-oscillations in the system is most probable when its operating conditions are sharply changed which is always accompanied by a transient period. When the system is stable the transient period terminates comparatively fast. After several periods of damped oscillations the system starts to operate under steady-state conditions.

When the system is unstable, oscillations arising during the transient period are not damped but are maintained for a long time and transfer into undamped self-

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oscillations of the system (section III). These oscillations in the power supply system are sometimes called "hunting" of the system. Hunting usually occurs in the system at high speed of the generators and low load in the mains.

The power supply system of a modern aircraft usually comprises several paralleled generators equipped with voltage regulators and minimum relays and storage batteries connected according to a certain diagram.

Therefore, stability of such a system is determined in the whole by stability of its separate elements.

A. Effect of Generator on System Stability

The generator stability depends in the main upon its regulation characteristic $I_{f.o} = f(I_{l.o})$ presenting dependence of the generator field current ($I_{f.o}$) on value of its load ($I_{l.o}$) at constant voltage and speed of the generator.

Regulation characteristics of TCP-CT-6000A starter-generators at 9000 r.p.m. are presented in Fig. 9.

It is known that the generator has the best stability if its field current ($I_{f.o}$) considerably rises with increase of load ($I_{l.o}$). The regulation characteristic of such a generator is represented by curve 1 in Fig. 9.

As angle α increases (initial angle of the curve inclination relative to X-axis), the generator stability grows and, vice versa, reducing angle α deteriorates stability.

For instance, a generator with regulation characteristic corresponding to curve 2 does not possess a sufficient margin of stability and if used in a common aircraft system (without application of special damping devices) will add to arising of self-oscillations (hunting) of the system. Curve 2 shows that the field current of such

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a generator with load changing from zero to a certain value (approximately to 50 per cent of rated load) remains practically constant. Moreover, some generators have the so-called "drop" of the regulation characteristic when the field current at a certain load (usually close to 1/2 of 1 rated value) is less than the generator no-load field current by value $\Delta I_{f,0}$. The generator with such a characteristic (curve 3) has minimum stability which is more evident with increase of $\Delta I_{f,0}$. All this is confirmed by a number of laboratory experiments.

The unstable operation of generators is most manifest at maximum speed (8000 - 9000 r.p.m.) at which the regulation characteristics are close to curves 2 and 3. On the contrary, at speeds of aircraft generators (series PCP and PCP-CT) of 7000, 6000 and 4000 r.p.m. when the regulation characteristics are of the ascending nature the operation of the generators is stable. In this case the regulation characteristics of the generators correspond to curve 1 which can be seen from comparison of Figs 9 and 10.

It must be noted that minimum stability of the system at high speed of the generators is resulting not only from unfavourable regulation characteristics of the generators, but depends also upon characteristics of voltage regulators operating in assembly with them and upon other factors.

Practically all aircraft generators of series PCP and starter-generators of series PCP-CT at maximum speed have regulation characteristics either with "drop" or with very small angle α at its beginning which does not always ensure, as was said before, proper stability of the system. With decrease of the generators speed the steepness of regulation characteristics grows and stability considerably increases. It may seem that it is not difficult to ensure ample steepness of the regulation

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characteristics at high speed, having thus solved the problem of the generators stability. But as it is necessary to have a wide operating speed range of the generators (from 3800 - 4000 r.p.m. to 9000 - 9300 r.p.m.) it is impossible to achieve it without a substantial increase of dimensions and weight of the generators. Really, if the ample steepness of the regulation characteristic at maximum operating speed is achieved, the generator will fail to supply the required output at minimum speed due to increase of the required field current. It is possible to decrease the required field current only by corresponding increase of the generator weight and dimensions or by increase of its minimum operating speed (approximately to 5000 instead of 4000 r.p.m.).

It is worth to consider the causes of the generator regulation characteristic "drop" at a high speed. The "drop" is the result of magnetizing effect of the commutating poles winding as well as of the generator armature reaction to the backward shift of brushes (carried out for better commutation and reduction of the so-called initial revolutions). As the required field ampere-turns of the main poles are relatively low at a high speed of the generator, it leads to a certain decrease of the required field current of the generator operating with some load as compared to its value at no-load operation which can be seen at a load of approximately 50 per cent of the rated load and lower.

The "drop" can be reduced or eliminated by decrease of magnetizing effect of the commutating poles winding (by reducing its ampere-turns or introducing diamagnetic gaskets between the commutating poles and the frame) and by forward shift of brushes. However, utilization of these measures on series generators is to a great extent limited, since the reduction of effectiveness of the

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commutating poles leads to worsening of commutation; forward shift of the brushes, besides worsening of commutation, leads to growth of the generator initial revolutions. Therefore, the above methods allow to practically reduce the value of the "drop" on aircraft generators of medium power approximately to 0.1 A or eliminate it. But it is impossible to obtain a considerably ascending regulation characteristic. Thus, no substantial increase of the generator stability at a high speed is achieved.

D. Effect of Voltage Regulator on System Stability

The voltage regulator has an essential influence upon the system stability which is particularly evident at a sharp change of the operating conditions. A transient period of voltage regulation when the generator load is switched off is presented in Fig. 11.

As can be seen from Fig. 11, at the first moment after the more or less substantial load across the mains is switched off the generator voltage rises instantly to value A, since the voltage regulator because of a certain lagging is not able to react instantly to this variation. Then the regulator starts to operate tending to bring the generator voltage to the initial level. However, due to the regulator inertia voltage re-regulation takes place as a result of which the voltage level decreases to a value which is essentially lower than the initial. Then, after point B the voltage rises again under the action of the regulator and again its re-regulation takes place. At point B the voltage becomes higher than the initial value but lower than at point A. Further, after several fluctuations with a diminishing amplitude the voltage variation ceases, the transient period terminates and the generator voltage is brought to the initial or a somewhat differing value by the regulator. Time T of the transient period

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is usually insignificant, it lasts about 0.15 - 0.2 sec. at switching off the rated load and 0.05 sec. at switching on.

It should be noted that duration of the transient period and stability of the regulator depend to a greater extent upon the regulator adjustment, characterized by the distance of its operating zone from the "chatter" zone at which the unstable operation of the regulator commences accompanied by undamped fluctuations of the regulated voltage. As the regulator approaches the "chatter" zone time T of voltage fluctuations damping increases during the transient period and at a certain moment these fluctuations are not damped at all and the regulator enters the period of unstable operation. Nature of such fluctuations is presented in Fig. 39.

Stability of the regulator as well as stability of the whole system worsens with increase of speed and decrease of load of the generators which is explained in relation to the regulator by two causes.

At a high speed and no-load conditions of the generator the regulator operates in a more sensitive zone in which the required variation of the carbon pile resistance is achieved by a slight shift of the regulator armature (Fig. 12). Besides, the regulator carbon pile in this case must develop the maximum resistance which is particularly important at the transient period (for instance, for point B, see Fig. 11) due to which danger of the carbon pile rupture arises and stability of the regulator and the whole system worsens.

The regulator operating point is chosen at a certain distance from point C (Fig. 38) which serves as a boundary between the zones of unstable and stable operation of the regulator. The closer the operating point to point C, the more sensitive is the regulator and the more accurate is the regulation. But at the same time stability of the regulator is decreased. Therefore, adjustment of the

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regulator near the "chatter" zone leads to unstable operation which is particularly evident during the transients and causes self-fluctuations of the whole system, the voltage regulator being one of its elements.

The above-mentioned phenomenon must be taken into consideration when adjusting the regulator and the operating point must be chosen at the greatest distance from the "chatter" zone. The latter can be ensured within certain limits restricted by the required accuracy of regulation. To considerably increase the regulator stability during the transients shunt stabilizing transformers, for instance T-17 transformer, are used for P-25A and P-27 regulators. However, while solving the problem of stability for a single generator operating without a storage battery, such transformers are not able to ensure sufficient stability of the system when paralleled generators operate with the storage battery. In this case stabilizing transformers of a series type are used, which have a series winding consisting of one or two turns energized by the generator load current. To such belong TC-9A, TC-9A-12 and other transformers.

Recently fluctuations differing in nature from the "chatter" condition were found in P-25AM regulators. Such fluctuations called "buzzer" condition are mainly attributed to vibrations of the regulator armature proper and to insufficient resistance of the carbon pile. A WPP-1A (WPP-1M) carbon pile used in P-25-AM and P-25A regulators had according to the Specifications a resistance of 30 ohms when in cold state.

Resistance of the pile in heated state was not specified and practically amounted to 20 - 25 ohms at a 5 gr pressure, while the resistance required for the generator steady-state condition amounted approximately to 28 ohms. It is evident, that the carbon pile can develop such a resistance not at 5 gr but at a lower

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pressure which results in extremely unstable operation of the regulator, arising of self-fluctuations, an excessive burning of the carbon pile discs and bringing the regulator out of operation. Such fluctuations cause in the earphones connected to the regulator carbon pile clicking resembling buzzing.

At the same time considerable radio disturbances appear in the aircraft mains. The "buzzer" condition usually appears at a high speed and no-load operation of the generator when the regulator is hot and particularly when it operates at high altitudes.

When the P-25AM regulator operates with generators having speed of not more than 7000 - 7500 r.p.m. the "buzzer" phenomenon does not occur.

Various disturbances, for instance, change of operating conditions, shocks of the regulator against the aircraft skin or neighbouring objects considerably facilitate appearance of the "buzzer" condition in the regulator.

Tendency of the P-25AM regulator towards the "buzzer" condition was one of the reasons for constructing a P-27 regulator.

In a new regulator a number of measures was taken to eliminate the "buzzer" conditions: heating of the carbon pile and other elements of the regulator was reduced by replacing the ceramic tube with a metal one and increasing the number of fins and diameter of the finned cooler; a new carbon pile WPP-9 is used its maximum resistance in heated state being 1.5 - 2 times more than that of the old one; armature with a diaphragm spring is replaced with an armature having petal-type springs.

The above-mentioned alterations made it possible to eliminate the "buzzer" condition in P-27 regulators functioning in modern aircraft at any operating condition.

It should be noted that similar alterations were also introduced in P-25AM regulators. For instance, at present

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a new carbon pile MP-1A with a guaranteed resistance of not less than 30 ohms in heated state is used in P-25AM regulators.

All this added to reliable operation of P-25AM regulators and allowed them to be used in a number of aircraft having favourable temperature conditions for operation.

However, on high-speed aircraft in which air temperature at places where regulators are installed is positive at high altitudes, reliability of the P-25AM regulators operating with MP-1A carbon piles is not sufficient, therefore, P-27 regulators must be used in such cases.

C. Effect of Storage Batteries on System Stability

A certain effect on the system stability is exerted by storage batteries connected in parallel with the aircraft generators.

Numerous tests proved that with a normally adjusted regulator operation of the generator without storage batteries is absolutely stable at transients. When the generator operates in conjunction with storage batteries, stability of the system is worsened which in certain cases leads to appearance of undamped fluctuations. This is true not only for several paralleled generators operating in conjunction with the storage battery but also for joint operation of one generator.

Fig. 13 shows operation of a FCP-CT-6000A generator at transients without a storage battery while Fig. 14 presents its operation at the same conditions in conjunction with a 12-CAM-28 storage battery. In the first case operation of the system is stable, while in the second one at a low-load condition stability of the system is

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disturbed and undamped fluctuations of the generator voltage and current and also of the storage battery current appear. This indicates that the storage batteries exert a certain unfavourable effect on stability of the whole system.

Worsening of the system stability with the storage batteries connected is explained by the fact that in this case variation of the generator regulator voltage at the transient period (for instance, when load is dropped) causes a corresponding variation in the storage battery charging current. Thus, at this period the generator load becomes variable due to the storage battery which causes the voltage regulator to react. This extends the transient period and in certain cases causes arising of undamped fluctuations.

Nature of the storage battery charging current variation with changing of the generator load is presented in Figs 8 and 14 from which it can be concluded that the storage battery can not only receive the charging current but supply the current to the generator depending upon the range of the fluctuations.

It is clear that at the same range of the generator voltage fluctuations and other conditions being equal the value of the storage battery current fluctuations will depend upon the battery internal resistance.

The storage battery current is equal to

$$I_{bat} = \frac{\Delta U}{R_{bat.int}}, \text{ where}$$

ΔU is the difference of the generator and storage battery voltages;

$R_{bat.int}$ is the battery internal resistance.

The less the value of $R_{bat.int}$ the greater is the storage battery current. Consequently, at a low internal

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resistance a certain variation in value ΔU causes greater variation of the storage battery current. Therefore, storage batteries with lower internal resistance contribute to a greater extent to worsening of the system stability as compared with storage batteries having higher internal resistance. This is proved by comparison of stability of two systems: one with a 12-A-30 storage battery operating in parallel with the generator and the other with a 12-CAM-28 storage battery.

It is known that internal resistance of the 12-CAM-28 battery is twice as low as that of the 12-A-30 battery ($R_{bat,int} \approx 0.04 \text{ ohm}$) and therefore, stability of the system with the 12-CAM-28 battery is considerably lower.

It is proved by the operating practice. It is known that in the past 12-A-30 storage batteries were used in aircraft and no disturbances of stability of the power supply system were practically registered. With introduction of 12-CAM-28 storage batteries, cases of arising of the system self-fluctuations were sharply increased which required special measures to increase the system stability.

D. Stabilizing Transformers with Series Turn

As aircraft generators must have small weight and wide range of speed, the possibility to increase their stability is extremely narrow. Improvement of serial generators in this direction yields no appreciable results.

The possibilities for increasing stability of voltage regulators to meet certain requirements as to accuracy of regulation are also very narrow. Besides, the regulator circuit is not capable of eliminating self-fluctuations of the system arising during parallel operation of generators and storage batteries.

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Thus, the performed improvement of generators and voltage regulators stability failed to essentially increase stability of the whole system and did not eliminate arising of self-fluctuations. Attempts to increase the system stability by using more powerful stabilizing transformers of common (shunt) type with the primary winding connected in parallel with the generator field winding also failed to yield desirable results, since in this case the pulse sent for damping the system lags considerably behind as compared with a disturbance.

To this type belong T-1A, T-1F, TC-8 and other transformers. Increase of power in such transformers also failed to practically ensure required stability of the system.

The problem of increasing the system stability was solved by connecting into the circuit stabilizing transformers TC-9A (and the like) with a series winding energized by the generator load current. Practically such a transformer is free from lagging and besides, variation of the generator current creates substantial pulses due to which a more powerful signal can be obtained for damping the system. Design and operating principle of series-type transformers are described in Appendix 2.

Usage of series-type transformers completely solved the problem of increasing stability of the system: aircraft generator - voltage regulator - storage battery (for a single generator and for several paralleled generators at all operating conditions).

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VI. DESIGN

A. P-27 Voltage Regulator

The P-27 voltage regulator (Fig. 15) consists of two main units: regulator 1 itself with resistors and terminal block 14. The regulator is fastened to the terminal block by means of bail 16 and hinged spring locks 15; it is an easily removable unit.

The regulator unit together with a plate and resistors consists of the following elements: regulator proper 1, temperature compensating resistor 17 (wire-wound vitrified resistor ПЗВ-25-20 ohms), stabilizing resistor 20 (wire-wound vitrified resistor ПЗВ10-1500 ohms) and plate 18 on which the circuit elements are mounted. Rheostat BC-25B (Ref. No. 19) is installed on regulator electromagnet case 6.

The main parts of the regulator (Fig. 16) are electromagnet 40 with armature 7 and finned cooler 10 with carbon pile 12. The electromagnet and finned cooler are attached to shaped bracket 34 by screws 47 and studs 11. The electromagnet consists of armature 7, case 4, coil 38 inserted into the case, cover 44 and core 43. All parts of the electromagnet magnetic circuit are made of steel.

Electromagnet case 4 is shaped as a cylinder. The case bottom has a through round opening with a chamfer to accommodate core 43. The side cylinder surface of the case has a trade-mark attached by two rivets and a lengthwise slot for passing the electromagnet coil leads.

Electromagnet cover 44 is made in the form of a disc having a projection which enters case 4 and centres the cover.

Provided at the centre of the cover is a large threaded hole for screwing in electromagnet core 43. Electromagnet cylindrical core 43 can be screwed in and out of the cover so as to change magnetic gap. To make

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the turning convenient a segment slot for a screw-driver is made on the core outer face.

Screwed into the outer side of the cover are two screws 42 which press plain steel washers 41 to the core projecting part thus counterlocking the core. The heads of screws 42 are locked with safety wire which after adjustment of the regulator are sealed at the manufacturing plant.

Three holes for the screws attaching the cover and case of the electromagnet to shaped bracket 34 are arranged on the cover at an angle of 120° to each other. Two of these screws at the same time attach disc 45 used for installing the BC-25B rheostat. Electromagnet coil is of cylindrical shape and has three windings: operating winding 1, temperature compensating winding 3 and paralleling winding (equalizing) 2. The coil windings are set on plastic former 46.

Operating winding 1 constitutes the first layer, equalizing winding 2 - the second, and temperature compensating winding - the third layer. The operating winding is insulated from the equalizing winding by two layers of varnished silk ММ-2 0.1 mm thick and one layer of electric cardboard ВВН 0.1 mm thick. The equalizing winding is wound on the electric cardboard. Two layers of varnished silk ММ-2 0.1 mm thick are placed between the equalizing winding and the winding of temperature compensation.

The outer surface of the coil is insulated by varnished silk ММ-2 0.06 mm thick. Output leads made of wire МРЧН 0.5 mm² in section are soldered to the leads of the windings excluding the lead of the compensating winding to which an output lead 0.35 mm² in section is soldered. The leads of the windings are bound in a common bunch wrapped by varnished silk ММ-2 (37). The varnished silk coating protects the insulation of the output leads from damaging against edges of the slot in the

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magnetic conductor body. The coil is impregnated with insulating varnish No. 447, while the upper layer of insulation is coated with electroenamel No. 1201.

Technological procedure for impregnating and drying the regulator coil is given in Appendix 4.

Placed between the electromagnet cover and the coil are packing washers 39 made of electric cardboard, which eliminate swinging of the coil in the electromagnet case.

The electromagnet armature rests against the face of duralumin ring 6 with an inner cone equal to 5° . Due to the conical surface of the ring it is possible to obtain a non-linear characteristic of the armature springs. The other face of the ring is provided with a boring which reduces the bearing surface of the ring.

The ring is separated from the electromagnet case with thin brass gasket 5 which while creating a diamagnetic gap prevents the armature from magnetic sticking when the latter rests against the electromagnet case face with the regulator at maximum operating conditions.

For selection of the required characteristic of the armature annular brass gaskets 35 are provided which make it possible to increase the gap between the armature and core of the required value.

Electromagnet case 4, conical ring 6 and armature 7 are centred by shaped bracket 34.

The electromagnet is attached to the shape bracket by three screws 47 passed through cover 44. Regulator finned cooler 10 is attached to the other side of the bracket by three studs 11. Studs 11 are insulated from the finned cooler with insulating bushings 25 and washers 24. The bracket is a shaped ring case of aluminum which has two lugs for installation on the plate. Each lug is provided with two threaded holes to receive screws 33 fastening the bracket to the plate.

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Temperature compensating resistor 26 is fastened to the vertical surface of one of the bracket lugs.

The screw fastening the temperature compensating resistor is insulated from the bracket by insulating bushings and washers and serves at the same time as an adapter terminal (projecting tail piece of the screw with washers and nut) for connecting the electric circuit when the BC-25E rheostat is removed from the regulator (see Section VII, Para. 6). The other lug is provided with a boss having a hole to receive the screw fastening stabilizing resistor 36.

Stamped cup 8 is installed between the bracket and finned cooler. It covers the regulator armature and serves as a thermal shield between the finned cooler and electromagnet. At the centre the cup is provided with a round hole to receive the finned cooler duralumin bushing. The side wall of the cup has a hole with a through rubber bushing for the armature lead. The cup is insulated from the finned cooler by a glass textolite washer stuck to the latter with glue 54-2.

Finned cooler 10 serves as a radiator for removal of heat radiated by carbon pile 12. Carbon pile 12 is placed into duralumin tube 13 with oxide-varnish insulating coating, press-fitted into the regulator finned cooler. The duralumin tube with a special oxide layer coated by a heat-resistant varnish ensures high-heat conduction and sufficient insulating properties.

Carbon pile 12 of MP-9 type used in the regulator is a variable resistor and consists of a stack of carbon discs about 0.8 mm thick. Outer diameter of discs is 16 mm, inner diameter 11 mm. Height of the pile is 57 mm.

The cooler is cast of aluminium alloy and has disc-shaped fins. Nine fins of equal thickness are

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uniformly arranged along the cooler length while the tenth fin is thickened and has a cylindrical recess for flange 21 and two small bosses.

The fins are provided with slits for studs 11 passing along the cooler and have a slit for the temperature compensating resistor attached to the lug of bracket 34.

The fins enlarge the outer surface of the cooler and thus increase dissipation of heat produced by the carbon pile during the regulator operation into the ambient air. For this purpose the finned cooler is painted black.

Flange 21 is installed at the centre of finned cooler 10 and is attached to it with two screws 20. Glass textolite gasket 14, washers 16 and ceramic bushings 15 insulate the flange from the cooler.

To ensure more reliable insulation of the finned cooler from the regulator body, cooler 10 is assembled with studs 11, flange 21, cup 8, bracket 34 and with insulating parts 14, 15, 16, 24 and 25 fitted on a bakelite varnish, and is dried during 30 min. in the air and then during one hour at a temperature of 70 - 80°C and one hour at a temperature of 100 - 110°C.

Faces of the flange and insulating gasket, the flange excluding its upper surface, insulating washers 16, metal washers 17 and 18, heads of screws 20 and the cooler face surface are coated with varnish No. 202 and dried during 1.5 hours at a temperature of 150°C.

Regulating contact screw 22 is turned into the flange threaded hole. It is used for compressing the carbon pile and bringing the regulator armature into the range of operating gaps during adjustment. Screw 22 has a socket housing carbon contact 23. The side surface of the socket is provided with longitudinal slits for tightening the socket to ensure more close fit of the

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carbon contact. The end of the adjusting screw enters insulating bushing 13 for which a tapered boring is made in flange 21.

The flange boss is provided with a slot running in parallel with its face which cuts through the threaded hole for the adjusting contact screw. The boss face has two threaded holes. Screw 26 used for counterlocking the adjusting screw is turned into the threaded hole running perpendicular to the flange slot (See Fig. 15). When the counterlocking screw is tightened, it compresses the slot which causes cocking of the thread and as a result the adjusting screw is locked. The second threaded hole is designed for screw 53 fastening cable shoe 31 of the carbon pile lead.

Heads of the cable shoe fastening screw and counterlocking screw are locked with safety wire 27 the ends of which after adjustment of the regulator are sealed at the Manufacturing plant. To prevent the seal from projecting beyond the regulator one end of the wire running from the seal is passed through hole 21 drilled in the flange boss at an angle of 60° to the face and is twisted together with the other end of the seal wire. This provides for a stationary position of the seal relative to the flange.

The regulator armature (Fig. 17) consists of disc 1, plate springs 9 and segment 11 with carbon contact 12. The armature base is disc 1 made of electric steel which serves as a magnetic conductor. Placed on the disc is hexagonal gasket 3 at the edges of which six groups of plate springs 9 consisting of three petals each are arranged.

Two thin (0.1 mm thick) brass hexagonal gaskets 4 ensuring secure fastening of the springs are placed between the latter at places of their attachment. The presence of gaskets 4 provides for more gentle sloping of the armature mechanical characteristic which is necessary

for better coincidence of the armature mechanical characteristic and the electromagnet pull characteristic.

Gasket 3, springs 9 and gaskets 4 placed between the springs are pressed to the armature disc by round steel washer 5 and six screws 2 and 7. Screws 7 and back washers 13 fasten the springs and brass segment 11 housing the carbon contact which serves as a current conductor to the carbon pile. Pressure of the armature springs is transmitted to the carbon pile through the segment and carbon contact.

The segment consists of two components: flat brass shaped part with three securing lugs and socket with tail-piece mounted in the centre of the segment and soldered to it. The segment socket made analogous with the regulator contact screw houses the carbon contact.

The segment is insulated from washer 5, screws 2 and 7 and washers 13 by means of insulating gaskets 6, ceramic bushings 8 and insulating washers 14. To increase the insulation resistance of segment 11 its fastening and insulating parts are coated with bakelite varnish during assembly. After assembly the armature is dried for one hour at temperatures of 70 and 150°C.

Then, the segment (on the outside), insulating washers, metal washers and mica gaskets are coated with varnish No.302 twice and dried at a temperature of 150°C during 2 hours after each coating. Wire 10 (1.5 mm² in section) is beaded into the segment projecting lug by means of special brass washer 16 and hollow copper rivet 15. This wire serves for electrical connection of the carbon pile with the generator field winding.

Plate 27 (Fig.16) is made of sheet duralumin and has four bent up low uprights and two projecting tenons for fastening the regulator on the terminal block. When the regulator together with the plate is installed on

the terminal block one of the tenons enters the terminal block bail while two lock springs attached to the block engage two uprights located opposite to this tenon.

Installed on the plate are five brass contact pins 31 intended for connection of the regulator unit circuit (through the contact plates of the terminal block) with the block terminals. Tail pieces of the pins are beaded onto cable shoes 32 to which are soldered leads from the regulator coil, resistors and the carbon pile.

The contact pins resting against brass washers are insulated from the base by insulating gaskets 28 and 29 and washers 30.

All connections in the regulator circuit wiring are soldered with HOC-40 solder excluding the connections of wires with resistors HGB-25-20 ohms and HGB-10-1500 ohms where usage of tin lead solders (HOC) is not permissible because of high temperatures arising during operation of the regulator. Therefore arc welding is used.

The terminal block with shock absorbers (Fig.18) is designed for connecting the carbon-pile regulator into the aircraft mains and protecting the regulator against vibration and shocks.

The P-27 regulator is furnished with terminal blocks of two kinds: left or right one.

Design of the left and right terminal blocks is quite identical. They differ only in location of hinged spring locks and terminals on the block (Figs 18 and 19).

The base of the terminal block is a rectangular textolite plate with four large round openings for shock absorbers, holes for terminal screws and fastening parts and a large rectangular cutting with chamfered edges for contact plates.

The terminal block mounts:

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(a) six terminal screws 14 designated with letters A, B, K, X and E used for coupling the connecting wires. Terminal screw E not connected into the regulator circuit serves as a spare one and is used in special cases (See Section VII);

(b) five spring contact plates 15 made of bronze, for connection of the terminal screws with the regulator plate contact pins;

(c) four spring shock absorbers 8 with adjusting screw-pins and nuts for fastening the terminal block on the aircraft;

(d) stop 13 serving to prevent the regulator from shifting relative to the block (the stop engages the regulator plate projection);

(e) bail 6 and two hinged lock springs 5 fastening the regulator unit together with the plate to the block and ensuring secure installation and quick removal of the regulator;

(f) two screws 4 fastening the clips installed during mounting of the wires connecting the shock absorbing block terminals with the aircraft mains.

The face of the terminal block is provided with inscriptions LEFT (ЛЕВАЯ) or RIGHT (ПРАВАЯ).

B. BC-25B Rheostat

The BC-25B rheostat is installed on the regulator distance disc. The external resistor bracket is fastened by two screws turned through the holes in the disc into the regulator magnetic conductor cover.

The BC-25B rheostat is designed as circular resistor 20 with slide 19 revolving on axle 21. The winding of resistor 20 is made of enamelled constantan wire H9K wound on glass-textolite circular former 4 with forced pitch. The resistor is insulated by gasket 5 made of electric cardboard and clamped in a circular groove of frame 6.

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Beaded at the centre of frame 6 are bushing 7 with external thread on its end, centring axle 21 which fastens frame 6 with nut 2 and rectangular hood 11 to bracket 3. The frame and bushing are insulated from the bracket and hood by textolite washer 12 and plastic bushing 10.

To insulate hood 11 from bushing 7 the hole in the hood is made of a larger diameter than that in insulating washer 12 due to which the insulating washer centred with the hole in the hood and attached to it with two rivets prevents any electrical contact between the bushing and the hood.

Slide 19, shunting part of the resistor, is fixed on the axle flats and secured with nut 16.

The slide is shifted along the resistor by turning knob 9 the latter being connected with its socket to the axle end. The upper part of the knob is centred by the bracket. To insulate the knob from the axle the socket is placed in plastic insulation 8 press-fitted inside the knob. To prevent the axle from rotation its end has a rectangular shape while the socket is provided with flats.

To eliminate self-turning of the slide, spring lock 1 attached to the bracket and meshed with the knob knurling is provided. To make the electric contact between the brass elastic slide and the resistor winding wire enamel is removed from the working face of the resistor. The electric contact between the slide and frame is ensured through axle 21, brass elastic washer 17 and bushing 7.

To protect the resistor against mechanical damage it is placed into a rectangular hood and closed with cover 15. Manufacturer's name-plate 18 indicating the type and number of the resistor and showing its trademark is riveted onto the hood top. To make the connection of the resistor into the voltage regulator circuit

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more convenient terminal plate 23 is attached to the hood by two rivets. The terminal plate is insulated from the hood by insulating gasket 13. Two brass threaded bushings clamping by their beads the resistor contact plates are press-fitted into the terminal plate.

The contact plates are soldered to the resistor ends, one of the contact plates being insulated from the frame by an insulating bushing, while the second is directly connected to the frame. To prevent the contact plates from shorting insulating gasket 14 made of sheet textolite is installed at the bottom of the cover. Rubber bushings 24 protecting wires from damage are inserted into the hood holes.

The bracket and the knob of the BC-25B rheostat are provided with arrows and inscriptions HIGHER (БОЛЬШЕ) and LOWER (МЕНЬШЕ) showing the direction of the knob rotation to increase or decrease the voltage maintained by the regulator. To connect the external resistor into the regulator circuit it is necessary to remove cover 15 and clamp the cable shoes with wires by screws 22. The BC-25B rheostat is fastened on the regulator to the bracket.

The overall and mounting dimensions of the rheostat are shown in Fig. 21. If the place for installing the regulator in assembly with the BC-25B rheostat is not sufficient or access to the rheostat is difficult it is permissible to remove the rheostat from the regulator and to install it at another place (See Section VII).

C. Capacitor KEM-31

The KEM-31 oil-paper, 4- μ F capacitor is placed in the rectangular metal housing. One of the capacitor plates is connected with an insulated lead installed on the housing, while the other plate is directly connected with the capacitor housing. The capacitor is fastened

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and connected to ground by two lugs of the housing and screws M3.

OPERATING AND MAINTENANCE INSTRUCTIONS

VII. INSTALLATION OF REGULATOR UNIT IN AIRCRAFT

Before installing the regulator in the aircraft, check that it incurred no mechanical damage during shipment or unpacking.

When choosing the place for installing the regulator in the aircraft, the following requirements must be observed.

1. The regulator must be installed at places where its heating by other devices and direct contact with them are excluded. The regulator must be protected from dirt, water, oil, fuel and casual mechanical shocks.
2. The regulator must not be installed in small compartments having poor heat dissipation. It is desirable to ensure air circulation adding to the regulator cooling and thus prolonging its service life.
3. During operation the temperature rise of the regulator finned cooler can amount to 200°C, therefore, the regulator must be installed at places where it can cause no damage to devices located nearby.
4. The voltage regulators must be easily accessible for inspection and quick removal.
5. When several regulators are to be installed, they should be located at places having approximately the same conditions (temperature of compartment, cooling conditions, etc.). Besides, symmetry of regulators location relative to the aircraft axis must be strictly observed. At the same time the regulators must be located so that minimum linear and vibration accelerations act along the carbon pile axis.
6. It is recommended to install in all aircraft the P-27 regulator with a left-hand terminal block. If the requirements listed in Para.5 cannot be met, use addi-

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tionally the P-27 regulator with a right-hand block.

7. Terminal blocks of the regulators must be installed so that their hinged locks fastening the regulator are easily accessible. The regulator must be installed in the aircraft on its shock absorbing terminal block.

To facilitate mounting of the terminal block, remove the regulator unit from it. For this purpose, pull back and swing out the spring lock from the uprights, raise one side of the regulator base and disengage its tenon from the block bail. The regulator terminal block must be installed in a horizontal plane with the regulator unit arranged above it.

The terminal block is fastened by studs of its shock absorbers. To ensure normal operation of the shock absorbers under conditions of vibration and consequently of the voltage regulator, the following measures should be taken during installation of the terminal block.

(a) see that the stud axes are not displaced relative to the axes of the shock absorbers and the bearing faces of the studs are arranged in one plane;

(b) use flexible conductors for connecting the terminal block to the aircraft mains; the conductors must be sufficiently long not to be strained when the block is shifted on the shock absorbers under conditions of vibration and jolting;

(c) wires connecting the shock absorbing block terminals to the aircraft mains must be clamped with clips fastened to the block with M3 screws on the side opposite to the hinged locks.

Insulation of the wires must be protected from damage caused by sharp edges of clips (in this case it is best of all to place a gasket of vinyl chloride plastic under the clip).

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8. In case the BC-25E rheostat is installed separately from the regulator (on the pilot's instrument panel or at another place easy of access) it should be removed from the regulator. In this case the two wires running to the regulator must be disconnected from the rheostat and clamped together with nut M (Fig.28) on the insulated screw fastening the resistor H9B-25-20 ohms to the regulator bracket. The BC-25E rheostat is cut into the circuit of the regulator operating winding between terminal X of the regulator block and terminal X of the TC-9A (TC-9AM) or TC-9A-12 (TC-9AM-12) transformer (Fig.5).

In some aircraft where the BC-25A resistor was installed directly on the P-25AM regulator, for installing the P-27 regulator it is necessary to remove the BC-25E rheostat and to install it separately close to the regulator, since the dimensions of the P-27 regulator exceed those of the P-25AM regulator.

In such aircraft terminal E on the regulator terminal block ensures connection of the regulator into the mains without changing the length of the mains wires and resoldering the cable shoes. The wires running from terminal X of the transformer is connected to terminal E of the P-27 regulator block but not to terminal X as was the case when the P-25AM regulator was used. Terminal E is installed near terminal X. The rest of the aircraft mains wires are connected to the terminals of the P-27 regulator block in the same way as they were connected to the P-25AM regulator (See Fig.22).

When the BC-25E rheostat is removed from the P-27 regulator the output leads running from the regulator to the resistor must be disconnected. For this purpose, remove the BC-25E rheostat cover, turn out the screws fastening the cable shoes to the rheostat terminal plate and carefully remove the conductors together with the shoes. The conductors must be fastened by nut M of the insulated screw securing the H9B-25-20 ohm resistor.

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The BC-25E rheostat must be installed separately from the regulator at a place specified in drawings for a given type of the aircraft. One output lead of the rheostat must be connected to terminal of the shock absorbing block and the other, to terminal E of the block.

The key diagram of connections in case terminal E is used is shown in Fig.22.

It is necessary to pay attention to fastening of wires running to the BC-25E rheostat in order to exclude any possibility for their breakage.

9. The KEM-31 capacitor must be installed as near as possible to the regulator at places where temperature does not exceed 70°C. The capacitor is fastened by means of lugs which should be cleaned of paint.

It is important to ensure reliable contact between the capacitor body and the aircraft structure. The capacitor lead is connected with terminal B of the regulator board with a conductor which must be as short as possible.

In wiring the regulator connection circuit and its elements special attention should be paid to ensure continuity of all wires and especially of wires running from terminal X of the regulator block to the BC-25E rheostat (if the latter is employed) and from the rheostat to terminal X of the transformer and further to the aircraft structure. Breakage of these wires leads to a sharp increase of the generator voltage which usually brings the generator out of operation, as well as storage batteries and a number of consumers having vital importance for ensuring normal flight of the aircraft.

Design of units and elements of the P-27 voltage regulator assembly provides for its easy and quick installation in the aircraft and replacement, if necessary, of its separate units (terminal block, external resistor).

It should be borne in mind that in certain types of aircraft where visual inspection is difficult, cases of

incorrect installation of the regulator on the board (the regulator plate tenon is not engaged with the shock absorbing block bail) are possible.

To avoid incorrect installation of the regulator on the shock absorbing board, carry out the following procedure:

(a) position the regulator at an angle to the shock absorbing block (Fig.23) and engage the regulator plate tenon with the block bail. Check the regulator for correct installation by applying effort to the left or right along the regulator axis. If the tenon is engaged with the bail, the regulator will remain stationary;

(b) press the regulator to the block surface and engage the block locks with the regulator plate uprights (Fig.24). The lock must be pressed simultaneously from below upward and towards the regulator;

(c) check the regulator for reliable installation by turning it along arrow A (Fig.25) with one hand while holding the block with the other. If the plate tenon is not engaged with the block bail, it will fall out of the block locks when the regulator is turned.

When installing P-27 regulators manufactured before December 1, 1956 in an aircraft, it is necessary to preliminarily check the value of gap B between the regulator plate tenon and the stop on the shock absorbing block on the side of the locks (Fig.26). The plate tenon located at the opposite side must completely enter the block bail and even project from it so that no gap (arrow A) is left between the bail and plate. Gap B between the plate tenon and the stop on the side of the locks must not exceed 1.5 mm. Otherwise the gap can be reduced by bending the stop.

It is not necessary to check the value of gap B on regulators blocks manufactured since December 1, 1956 which due to reducing of allowances for manufacturing shock absorbing panels, does not exceed 1.5 mm.

Drawings of overall dimensions of P-27 regulators with right- and left-hand terminal blocks are given in Figs 27 and 28 while recommended connection diagrams, in Figs 22, 29 and 50.

VIII. REQUIREMENTS TO CIRCUITRY FOR PARALLELED GENERATORS

To improve the uniformity of load currents distribution among the paralleled generators the generators, regulators, minimum relays and stabilizing transformers must be connected so that circuit of each generator and especially of power lines is balanced. Unbalance of the circuit leads to worsening of load distribution between the generators.

Values of permissible voltage drops across power sections of the generators' circuits with the system in cold state and the resistance value of equalizing windings in the generators are given in Table 1.

Balancing of circuit III-earth sections has the greatest influence upon the load distribution among the generators, since the voltage drop across these sections affects equalizing windings of the generators. Balancing of sections II-II' has also a considerable influence upon the load distribution, since the voltage drop across these sections does not affect the voltage regulators. Therefore, special attention should be paid to balancing of these sections of the circuit.

Unbalance across sections I-I' has only a slight influence upon the current distribution of the generators, since this unbalance is compensated for by the voltage regulators which maintain the voltage between terminals GENERATOR (PEH.) of the minimum relays and the common minus of the aircraft structure.

Table 1

Nos	Section of circuit	Designations in Fig.5	Voltage drop at rated current, V	Resistance, ohms
1	From generator plus terminal to terminal GENERATOR of differential relay	I-I'	0.5	
2	From terminal STORAGE BATTERY (BAT.) of differential relay to main plus busbar	II-II'	0.4	
3	From generator minus terminal to common minus of aircraft structure	III-earth	0.55	
4	From special terminal on ballast resistor to equalizing busbar (without paralleling winding of regulator and winding of TC-9A transformer)	III'-IV	-	0.1

Notes: 1. Values of voltage drops and resistance for circuit similar sections of the generators must not differ by more than 10 per cent. The absolute values of voltage drops across the circuit sections (or their resistors) may be allowed somewhat to depart from the

rated values given in Table 1, but the unbalance of the circuit (i.e. unbalance of the resistances across the similar circuit sections of all the generators) is absolutely impermissible since it affects the distribution of load among the paralleled generators.

- Variation of the resistance value and voltage drops across sections I-I' and II-II' is permissible on condition that sum of voltage drops across these sections does not exceed 0.9 V and balancing of the resistance across the corresponding circuit sections is maintained for all the generators.
- Value of resistance across the circuit power sections is different for generators with output of 3000, 6000, 9000 and 12,000 W and is obtained as a result of dividing the above-mentioned voltage drop by the generator rated current. For instance, resistance across section I-I' for a starting generator FCP-CT-6000A should be $\frac{0.5}{200} = 0.0025$ ohm.

IX. CHECKING REGULATOR OPERATION AFTER INSTALLING IT IN AIRCRAFT

After installing the regulator and its auxiliaries in the aircraft it is necessary to check their operation. Being sure that the BC-25B rheostat slide is set according to the Manufacturer's mark, check the operation of each regulator with the aircraft engine in action (this check must be carried out while testing the other units).

The check should be carried out (separately for each regulator) as follows:

- Cut the generator of a checked regulator in parallel with the storage battery by means of a tumbler

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switch (the rest of the generators must be out out).

2. With the aircraft engine speed not less than 500 r.p.m., read the voltage of the checked generator by a voltmeter. The voltage must be within 27 - 30 V. The generator load may be of any value but must not exceed 75 per cent of the rated value.

3. Increase the aircraft engine speed approximately to 8000 - 9000 r.p.m. while watching the readings of the voltmeter: practically the generator voltage must remain constant (its variation as compared to the initial value must not exceed 1 - 2 V).

4. Decrease the generator load (load drop) as possible; no continuous oscillations of the voltmeter and ammeter pointers are allowed (their oscillations must be damped during not more than 2 sec.).

If separate defects are detected during the check up it shows that faults were made in the connections which must be eliminated according to the instructions given in Section "Troubles and Remedies". When fluctuations of the generator voltage are noted, check the transformer for correct connection.

After elimination of defects, repeat the check up to make sure the generator operates normally.

X. PARALLELING GENERATORS

Upon checking the aircraft generators for correct connection it is necessary to adjust the generators for parallel operation. After proper adjustment the P-27 voltage regulator with the balanced connection circuit of the generators ensures a satisfactory distribution of load among the paralleled generators.

To adjust the aircraft generators or starting generator or operating in conjunction with the P-27 voltage regulators for parallel operation, proceed as follows:

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1. Set the slides of the BC-25E rheostats of all the paralleled regulators according to the Manufacturer's mark (or in the medium position).

2. Start the aircraft engines and warm up the regulators during a warming up period of the engines.

3. Adjust the aircraft engines for an average service speed.

4. Set all the generators with the help of the BC-25E rheostats at equal voltage (28 V A.C.) at no-load condition by switching off each generator in turn. After adjustment the generator may be again cut into the circuit or kept switched off depending upon the common load in the circuit.

To increase the voltage, turn the slide of the BC-25E rheostat clockwise, to decrease - counter-clockwise.

5. Cut all the generators into the aircraft mains.

6. During flight, load the generators approximately to 75 per cent of the rated current (for each generator) and equalize their currents by means of the BC-25E rheostats.

7. After 30 - 60 min. of flight when the whole system is warmed up, define more accurately the position of the BC-25E rheostats, for which purpose equalize currents of all the generators changing the position of the rheostat slides. For generators with a heavy load current, decrease the voltage by turning the slide counter-clockwise, for generators with insufficient load, increase the voltage by turning the rheostat slide clockwise.

8. When the generator currents are equalized, stop their paralleling.

During subsequent flights, do not change the position of the BC-25E rheostat slides. Check periodically the values of currents and voltages of the generators.

- Notes: 1. Should it be impossible to load the generators up to 75 - 100 per cent of the rated value, adjust the generators for parallel operation at maximum possible load.
2. On aircraft with no access to EC-25E rheostats during flight, adjustment of the generators for parallel operation must be carried out on the ground. In this case, adjustment according to Para. 6 must be carried out approximately at 50 per cent load and during a limited period of time to avoid burning out of the generator possible without forced air cooling. Adjustment described in Para. 7 is not to be carried on the ground and during the flight the generator currents should be checked. If the unbalance of currents after the flight is considerable, correct the adjustment according to Para. 6 on the ground.

The value of permissible current variation of the aircraft paralleled generators must not exceed 20 per cent of the rated value. For instance, the difference of currents for ICP-CT-6000A starting generators at loads close to the rated value must not exceed 40 A. At the same time the load of each generator must not exceed the rated value. At light loads a larger difference of currents is permissible since it is not dangerous for the generators which are underloaded. In case the difference of currents exceeds the permissible limits it is necessary to parallel the generators for the second time.

XI. OPERATION

A. Checking Regulator Performance

Wear of the carbon pile as well as possible permanent set of the armature springs due to continuous operation of the P-27 regulator may affect the adjustment of the regulator. In this case the operating zone of the regulator will approach the zone of unstable operation as a result of which the regulator may be involved into "chatter" condition which is followed by voltage fluctuations and may disturb the normal operation of the aircraft electrical equipment.

First of all, the "chatter" condition has a very detrimental effect upon the carbon pile causing destruction of separate carbon discs and bringing the regulator out of operation. Besides, disturbances in connections of the regulator separate circuits, in contact connections between the regulator and the terminal block, loosening of the block fastenings are possible during operation and may hamper the regulator normal operation. Therefore, during operation, check periodically the attachment of the terminal block, reliability of contacts and connections and the condition of the regulator adjustment.

During operation break of contact at the joint of the regulator unit contact pins and the contact plates of the terminal block is possible due to dirt and damage of the anti-corrosive coating of the contacting surfaces or weakening of the contact pressure because of bent terminal block contact plates. In this case the voltage may either increase excessively or completely disappear. To prevent such a defect, inspect the contacting surface during the routine maintenance. If the contacts are dirty, wash them with clean gasoline (never remove dirt or corrosion traces with emery cloth) and check the contact pressure of the terminal block contact plates exerted on the regulator contact pins. If the contact pressure is less than 1 kg,

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bring it to normal (not less than 1 kg) by bending the terminal block contact plates towards the regulator contact pins.

It is recommended to check the contact pressure of the normally operating regulator only after its guaranteed service life is expired and to inspect the contacting surfaces twice a year.

"Chattering" of the regulator can be detected by fluctuations of the voltmeter pointer, checking the generator voltage and by an increase of radio interference. A "chattering" regulator on the aircraft can be detected by successive connection of the generators into the aircraft mains (with the storage battery out out). At maximum speed, cutting in and out of the load of each generator is performed, the value of the load being not less than 50 per cent of the rated. If the voltmeter pointer of one of the generators shows continuous fluctuations, it means that the regulator of the given generator operates in the "chatter" condition.

The "chatter" condition, as was mentioned above, is easy to detect. Taking into account that the "chatter" condition has a detrimental effect upon the operation of the electrical equipment it is very important to replace the regulator close to the "chatter" condition in time. For this purpose, periodically (after each 100 hours of operation within the guaranteed service life and after 50 hours of its expiration) check the regulator adjustment by listening to the operation of the carbon pile with earphones. The earphones must be connected to terminals A and B of the regulator terminal block.

Checking the regulator operation must be carried out at a high speed of the generator (8500 - 9000 r.p.m.) by cutting the load in and out. During this check the storage battery must be disconnected from the mains. When the regulator operates normally, the load drop is accom-

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panied by a single click or several clicks lasting 1 - 2 sec. and by changing of tone heard in the earphones. If continuous clicks (over 2 sec.) or rattling are heard in the earphones, it means that adjustment of such a regulator is disturbed and close to the "chatter" condition. Such a regulator must be removed from the aircraft and sent to a special workshop for repair (checking and readjustment).

Never adjust the regulator on the aircraft by turning the electromagnet core and adjusting screw.

During the regulator operation the level of the regulated voltage may change. Adjustment of the voltage level to the required value is carried out by means of the BC-25B rheostat. Equalizing of currents of the paralleled generators is also carried out by means of this rheostat.

Defective regulators, transformers and capacitors belonging to these regulators, must be removed from the aircraft and replaced with new ones. The regulator is easily removed from the board and a new regulator is installed in its place. Newly installed regulators and their elements need no matching. It is necessary to adjust the required level of voltage by means of the BC-25B rheostat to equalize the currents of the paralleled generators, i.e. to carry out adjustment for parallel operation according to instructions given in Section X.

To avoid incorrect installation of the regulator on the shock absorbing block it is necessary to observe the instructions given in Section VII.

B. Operation of Paralleled Generators

When operating the aircraft paralleled generators, proceed as follows:

1. During the first flights, make sure that generators are correctly adjusted for parallel operation and, if necessary, carry out adjustment according to instruc-

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tions given in Section X.

2. During further operation, check the load distribution among the generators and carry out adjustment only when summary load across the circuit is heavy and possibility to overload separate generators exists. When the load across the circuit is low, overloading of the generators is practically impossible, therefore, in this case load currents of the generators need no constant control.

3. When faulty operation of one of the paralleled generators is detected, especially in case of a considerable rise of voltage (which can be noted by a sharp increase of the output current), disconnect such a generator from the mains in due time and decrease the load if the remaining generators are overloaded. To disconnect the faulty generator, use a tumbler switch.

4. If one of the generators despite the considerable load across the mains does not supply current, switch off its tumbler switch, check and, if necessary, increase the generator voltage by means of the BC-25E rheostat. Then cut the generator into the mains with the tumbler switch again. If the generator does not pick up the load it must be disconnected from the mains to avoid a certain drop in voltage of other generators (due to action of paralleling windings of the generators).

During operation, see that reliable tightening and contact is ensured at places where power supply conductors of the generators are connected, since poor contacts under heavy currents may cause an increase of voltage drop at such places and worsen distribution of load among the generators.

Certain phenomena met with during operation are described below.

During operation of the aircraft paralleled generators in case of low loads in the aircraft mains which

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are much lower than the permissible summary load of all the generators temporary disconnections of separate generators from the mains are possible due to functioning of the DMP-400 differential minimum relay (or its modified versions DMP-400A and DMP-400AM). The remaining generators are cut into the mains ensuring uninterrupted power supply to consumers.

This phenomenon may be caused by a certain unbalance of voltages and loads of the generators practically always present during parallel operation. It may also depend upon the characteristics of the differential minimum relay. With low loads across the mains, some of the generators or one of them (with lower voltage) may consume current from the mains and when this current rises to the value equal to the back spill current of the DMP-400 relay the latter automatically disconnects the generators from the mains.

The above-mentioned cases are most probable with variation in the operating conditions of the generators (load drop, changed in generators speed, especially when speed of one of the generators increases and that of the other decreases). In this case unbalance of generator voltages and disconnections of the generators from the mains are most probable.

Temporary disconnections of separate generators from the mains caused by functioning of the differential minimum relay due to low loads across the mains are quite normal and permissible since the generators remaining cut into the mains will completely ensure the power supply to the consumers due to low loads across the mains being at the same time considerably underloaded. The disconnected generators are automatically cut into the mains with increase of load and take up part of the load.

Temporary disconnections of separate generators due to functioning of the differential minimum relay are pos-

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sible at a load across the mains up to 25 per cent of the total rated load of all the generators. When loads are higher, this phenomenon does not occur. It should be noted that in certain emergency cases when the voltage of one of the generators is excessively high as compared to the rest of the generators disconnection of the latter from the mains is possible even at considerable loads and successive connection of the generators into the mains becomes difficult or impossible. This may happen when the current of the generator operating winding is broken with the generator operating with short shunt and its voltage being very high. Such a generator must be immediately disconnected from the mains.

Another similar phenomenon connected with operation of the DMP-400 differential minimum relay may be encountered during adjustment for parallel operation or in the process of operation, i.e. after one of the generators has been connected into the mains the other generators having the same voltage are not connected into the mains. This takes place due to the fact that the DMP-400 relay functions and connects the generator into the mains only in case when its voltage exceeds that in the mains by 0.3 - 0.7 V.

Therefore, the first generator with voltage considerably exceeding that of the storage battery is readily connected into the mains. As the generator regulators are adjusted approximately to equal level, then at low load connection of the next generator may be not effected since its voltage and the mains voltage (depending now on the voltage of the connected generator) are approximately equal. With increase of load the next generator is automatically connected into the mains due to action of equalizing windings of the voltage regulator.

For explanation we shall consider parallel operation of two TCP-6000A generators. If the generators are

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adjusted for equal voltage level and the mains load approaches zero, one of the generators will be out into the mains while the other having voltage equal to that of the first generator will remain out. If the mains load rises, for instance, to 50 A, it will be taken up by the first generator and a voltage drop of about 0.1 V will be registered across its ballast resistor EC-6000. Then current will flow through the regulator equalizing windings of both generators due to which voltage of the first generator will be reduced approximately by 0.35 V and that of the second generator will be increased by the same value (the figures are given for a case when total resistance of the wires in the circuit of equalizing windings of the regulators is equal to 0.2 ohm and the circuit has no TC-9A transformer).

Thus, the voltage level of the first generator will be by 0.7 V higher than that of the first one; the DMP-400 relay will function and connect the second generator into the mains. The latter shares part of the load and voltage of both generators will be equalized returning to the initial level.

When two TCP-6000A generators are connected into the mains, the third one having voltage equal to that of the first two generators may be connected provided a total load of about 100 A is ensured (50 A per each connected generator).

If voltages of two paralleled generators are adjusted for different levels, for instance, voltage of the first generator is higher than that of the second one by 1 V, then the first generator will be out in first, while the second one will be out into the mains at a load of about 125 A (the load is shared by the generators unequally).

In case the circuit is provided with a TC-9A transformer, the value of load necessary to connect the next generator into the mains is approximately 30 per cent

higher than that required in the circuit without the TC-9A transformer (i.e. with T-11 transformers).

Thus, when the mains load is low, disconnection of separate generators is not dangerous as those generators are automatically connected into the mains with increase of load.

In case of low load all three generators may be connected by means of tumbler switch. To this end set the tumbler switch of the first generator to the ON (ВКЛЮЧЕНО) position, then turn it off and connect the second generator, after turning off the second generator connect the third one and turn it off. After that set tumbler switches of all the generators to the ON position, thus connecting the generators to the aircraft mains (the contact of the differential relays being closed). It should be borne in mind that one or the other of the paralleled generators (having low voltage) may disconnect from the mains in case the difference in voltages of the generators is sufficient for relay ДМР-400 to operate.

G. Ground Check of Regulator

To check the P-27 regulator on airfield it must be removed from the aircraft and tested on a special panel. The panel is equipped with an equivalent generator or ICP -3000M generator and is wired according to the diagram shown in Fig.30 and instructions given in Section XII. The panel circuit diagram may be considerably simplified by removing some of its elements: storage battery, resistor R₁, ammeter A₂, voltmeter V₂, contactor K₁, etc.

To check the regulator, proceed as follows:

1. Install the regulator on the panel.
2. Set the BC-25B rheostat knob so that its resistance is approximately 4 ohms.

3. Note the regulator operating characteristics in a cold state at no-load and when the generator is loaded for which purpose proceed as follows:

- (a) start the generator at no-load and bring its speed to minimum;
 - (b) set the average speed;
 - (c) increase the generator speed to maximum value;
 - (d) cut the load in and out for three times;
 - (e) set the average speed of the generator;
 - (f) reduce the speed to minimum;
 - (g) repeat the same procedure for the loaded generator.
- Note the generator voltage at all operating conditions.

4. Determine the variation of the regulated voltage level by the BC-25B rheostat at an average speed of about 6500 r.p.m. and no-load operation of the generator.

5. Check the regulator operation for stability.

- (a) warm up the regulator for 10 - 15 min. at a field current of the generator equal to 3.5 - 4.5 A;
- (b) set the maximum speed of the generator (field current 0.9 - 1.1 A) at no-load running;
- (c) cut the load in and out for three times while listening to the operation of the carbon pile through the earphones connected across panel terminals A and B.

Note: If the panel is equipped with the equivalent generator its operating condition is set by the field current as instructed in Table 2.

The P-27 regulator is considered fit for service and may be installed in an aircraft again on condition that:

- (a) variation of the generator voltage when checked according to Para.3 does not exceed 2.7 V;
- (b) when checked according to Para.4 by the BC-25B

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rheostat, the regulator makes it possible to set the regulated voltage level to 28.5 V and then to increase it by not less than 0.5 V and decrease it by not less than 2 V;

(e) when checked for stability according to Para. 5, one or several clicks followed by a sound of even tone or quickly damped (during 1 - 2 sec.) oscillations arising during transients in regulation must be heard in the earphones.

If the regulator does not meet the above-mentioned requirements, it should be sent for repair to a workshop.

D. Recommendations on Preventive Maintenance of Regulator

To carry out the preventive maintenance the regulator must be removed from the aircraft and subjected to inspection and testing on a special panel. The panel is wired as instructed in the previous Section.

When performing external inspection, make sure that the wiring is intact and secure and that no mechanical damages and other defects which may disturb normal operation are found in the regulator and its elements.

Further, check the regulator for reliable operation according to the following procedure:

1. Install the regulator on the panel.
2. Adjust the BC-25B rheostat to about 4 ohms, by setting its knob to the appropriate position.
3. Test the regulator as instructed in Paras 1 - 5 of Section XI "Testing Regulator". When cutting the load in and out at maximum speed of the generator, listen to the carbon pile operation through the earphones.
4. At the average speed and no-load operation of the generator, check the BC-25B rheostat operation and the minimum and maximum levels of the regulated voltage ensured by this rheostat.

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The regulator is considered to be in good condition and ready to be installed in an aircraft for further service without adjustment if it meets the following requirements:

(a) the regulator is free of external defects hampering its serviceability;

(b) voltage variation when the regulator is checked on the panel according to Paras 1, 3 and 4 of Section XI "Testing Regulator" does not exceed 2.7 V;

(c) the BC-25B rheostat should be capable of setting the level of the regulated voltage equal to 28.5 V and then increasing it by not less than 0.5 V and reducing it by not less than 2 V;

(d) when the load is cut in and out, one or several clicks followed by a sound of even tone or quickly damped (during 1 - 2 sec.) oscillations arising during transients in regulation are heard in the earphones connected across the carbon pile.

If the regulator does not meet the above-mentioned requirements, it should be sent to a workshop for checking and repair.

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E. Troubles and Remedies

Trouble	Cause	Remedy
1	2	3
1. Voltage below rated value	(a) Permanent set of regulator armature springs. Turn-to-turn short-circuit in BC-25E rheostat winding	(a) Increase resistance of BC-25E rheostat by turning resistor slide clockwise. If voltage remains below rated value replace BC-25E rheostat (b) Replace regulator
2. Excessive voltage which cannot be adjusted by BC-25E rheostat	(b) Break in temperature compensating winding (a) Poor contact between regulator contact pin and contact plate X of terminal block due to dirt on contact surfaces or bent contact plate	(a) Eliminate trouble by washing contact surfaces with clean gasoline. Check pressure of terminal block contact plates on regulator contact pins. If pressure is less than 1 kg, increase it to rated value by bending contact plates towards regulator contact pins

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1	2	3
	(b) Break in circuit between terminal X of terminal block and terminal transformer (c) Break in secondary low-resistance winding of transformer (d) Break in BC-25E rheostat winding (e) Break in operating or burning out of regulator temperature compensating winding resistor (f) Terminal MCT of T-11 transformer or negative terminal of TC-9A transformer is not connected with minus (aircraft structure)	(b) Check circuit and correct trouble (c) Replace transformer (a) Replace resistor (e) Replace regulator (f) Restore connection of mentioned terminals with minus Replace regulator
3. Voltage above rated value. BC-25E rheostat fails to bring it to normal	(a) Excessive wear of carbon pile (b) Partial short-circuit of regulator winding	
4. Voltage fluctuations	(a) Faulty operation of regulator shock absorbers during vibration; break of terminal block shock absorbers, incorrect installation of block,	(a) Replace faulty terminal block or install block correctly and lengthen connecting wires

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1	2	3
	insufficient length of wires connected to terminal block (b) Intermittent contact at joint of regulator contact pins and contact plates of terminal block due to dirt on contact surface or loosening of contact pressure (c) Break in primary high-resistance winding of transformer (d) Break of wire connecting terminals A of regulator terminal block and transformer (e) Regulator out of adjustment due to excessive wear of carbon pile and entered the "chatter" condition	(b) Eliminate trouble by washing contact surfaces of regulator contact pins and terminal block contact plates; check and, if necessary, increase contact pressure to normal (not less than 1 kg) by bending contact plates towards regulator contact pins (c) Replace transformer (d) Repair break (e) Replace regulator

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1	2	3
5. Poor distribution of load among paralleled generators	(f) Puncture of insulation of tube housing carbon pile (a) Large difference of regulator voltages (b) Break in equalizing winding of separate regulators (c) Break of wires in circuit of regulator equalizing windings (from special terminals of ballast resistors to equalizing busbar) (d) Break in TC-9A transformer winding connected into circuit of regulator equalizing windings (a) Poor contact between regulator contact pins A and B and corresponding contact plates of terminal block due to dirt on contact surfaces or unbending of terminal block contact plates	(f) Replace regulator (a) Balance voltages (and currents) of generators by means of BC-25B rheostats (b) Replace regulator (c) Eliminate break (d) Replace faulty TC-9A transformer (a) Eliminate trouble by washing contact surfaces with clean gasoline; check and, if necessary, increase contact plates on regulator contact pins to normal
6. No voltage		

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1	2	3
		(not less than 1 kg) by bending contact plates of terminal block
(b) Break in circuit of regulator carbon pile (between terminals A and B)	(b) Locate break and eliminate it w/o disassembly of re- gulator. Should it be impossible, replace regulator	(d) Eliminate break
(c) Break of wires in circuit of generator field winding; between terminals GENERATOR relay JMP-400AM and regulator terminal B or between generator terminal III and regulator terminal A		
(d) Break in generator field winding		(d) Replace generator

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XII. CHECKING, REPAIR, ADJUSTMENT AND TESTING OF REGULATOR

Reconditioning and repair of the P-27 voltage regulator removed from the aircraft because of various faults are carried out in repair shops specially equipped for disassembly, assembly, adjustment and testing of the regulator.

Minor repair which does not involve disassembly and adjustment of the regulator is carried out directly in the airfield. When performing reconditioning jobs, use should be made of regulator P-27 spare parts listed in Appendix 5.

A. Equipment and Instruments

Repair, adjustment and testing of the carbon-pile regulator require the following equipment and instruments.

1. Generator

For adjustment and testing of the regulator employ the type of generator used with the regulator in the aircraft (for example, with a ICP-3000M generator).

The P-27 regulator can be used for operation with IC and ICP generators and ICP-CT starting generators having output of 3000, 6000, 9000 and 12,000 W and field current of 0.9 to 5 - 8 A. According to the Specifications the regulator should be adjusted and tested when operating in conjunction with the ICP-3000M generator, the operation of the regulator with generators of other types being guaranteed.

As it is important to ensure operation of the regulator within the above-mentioned limits of the generator field current variation and corresponding output dissipated across the carbon pile, it is allowed to adjust and test

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the P-27 regulator with an equivalent low-output generator providing for the limits of the field current close to permissible value and having corresponding resistance across the field winding.

Thus, for the equivalent generator use can be made of a generator which requires field current within the limits from 0.9 to 5 - 6 A with permissible speed and load variations and which has the resistance across the field winding equal to approximately 2 ohms.

2. Electric Motor

To drive the generator during adjustment and testing of the regulator it is necessary to use an electric motor of proper power ensuring variation of the generator speed within the given limits.

If the generator is adjusted and tested with the help of a RCP-3000M generator or another generator of the same series, use must be made of the electric motor having corresponding power and speed range from 4000 to 9000 r.p.m. (a standard bench for testing generators can be used for this purpose).

5. Panel

Adjustment and testing of voltage regulators are carried out on a special panel equipped with the regulator terminal block, T-11¹ transformer, load for generator, and storage battery. The panel is wired according to the diagram given in Fig.30 and must be equipped with the following D.C. meters:

1. Voltmeter V_1 for measuring the generator voltage within 30 - 45 V; division value 0.2 V, accuracy class - 0.5.
2. Voltmeter V_2 for checking functioning of the regulator paralleling winding within 1 V; accuracy class - 1.

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3. Ammeter A_1 for measuring the generator field current within 15 A; accuracy class - 1.

4. Ammeter A_2 for measuring the regulator operating winding current within 1.5 A; accuracy class - 1.

5. Ammeter A_3 for checking the generator load current; accuracy class - 1.5. Its measurement range must correspond to the rated current of the used generator.

6. High-resistance earphones T for checking operation of the regulator carbon pile.

4. Installation for Mechanical Treatment of Regulator

The installation includes:

- (a) regulator terminal block;
- (b) contactor or relay;
- (c) interrupter ensuring making and breaking of the contactor winding circuit with a frequency of 60 times per minute (the interrupter must be driven with a proper meter, for example, CA-60 meter).

The installation is assembled according to the diagram given in Fig.31.

5. Set of Special Tools for Repair and Adjustment of P-27 Regulator (Fig.32)

B. Trouble Shooting in Carbon-Pile Regulator

To detect the regulator faults, subject it to external inspection, check its operation and measure electric parameters of the regulator circuit elements.

During the external inspection, check that the regulator elements are not damaged and separate connections of the circuit are not broken.

Preliminary checking of the regulator operation must be carried out according to the following procedure.

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1. Install the regulator on the panel terminal block wired according to the diagram given in Fig.30.

Set the BC-25E rheostat slide according to the Manufacturer's mark (or into the middle position).

2. Start the generator, run it idle and set the minimum operating speed (field current of the equivalent generator must be within 2.5 - 2.8 A).

3. Check the generator voltage by the readings of voltmeter V_1 and the regulator operating winding current by readings of ammeter A_2 .

If the generator voltage is too high (above 40 V) and current across the regulator operating winding is zero, it shows that there is a break in regulator operating winding ℓ_1 , in temperature compensating resistor R_1 or in adjusting resistor R (BC-25E rheostat).

If the high voltage of the generator causes excessive current across the regulator winding (above 1.1 A), the trouble is caused by a turn-to-turn short-circuit in the operating winding or by considerable out-of-adjustment of the regulator.

If the generator voltage is too high, immediately switch off the generator and eliminate troubles detected in the regulator.

4. Set the voltage to 28.5 V by means of the BC-25E rheostat and raise the generator speed to maximum (field current must be within 0.9 - 1 A). For several times out the generator rated load in and out (50 A for the equivalent generator), and listen to the carbon pile operation through the earphones connected to terminals A and B of the terminal block. Normal operation of the regulator is accompanied with a single click and changing of tone heard in the earphones.

When the noise in the earphones shows that the regulator is out of adjustment while house sound indicates burning out of the carbon pile. In such regulators,

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check the condition of the carbon pile and replace either burnt discs or the whole pile. This done, adjust the regulators.

When checking the regulator circuit elements, refer to Fig.15 presenting design of the regulator and the key diagram given in Fig.4.

1. Disconnect wire 30 connecting the carbon pile with contact pin A for which purpose, remove safety wire 27, turn out screw 33 and take out washer 32.

2. Unsolder the wire located on vitrified resistor R_1 (H9B-25-20 ohms) lead which connects the resistor with the end of compensating winding ℓ_2 .

3. Remove the BC-25E rheostat from the regulator and take out the rheostat cover.

4. Check the BC-25E rheostat for reliable contact between the slide and the winding and for absence of turn-to-turn short-circuit. For this purpose, connect the probes (for instance, probes of RT-2 tester) to the contact screws of the rheostat; when the slide is shifted, the resistance of the BC-25E rheostat must gradually change from 0 to 6 ± 0.3 ohms.

5. Check the resistance value of resistor R_1 between its leads. The resistance must be within 19 - 21 ohms.

6. Measure the value of stabilizing resistor R_2 between contact pin A and connection of winding ℓ_1 lead with resistors R_1 and R_2 . The resistance must be 1500 ± 150 ohms.

7. Check the resistance of regulator operating winding ℓ_1 . Measuring must be carried out between the BC-25E rheostat contact pin to which common lead of winding ℓ_1 and ℓ_2 is connected and place where R_1 and R_2 are connected with the beginning of winding ℓ_1 . The resistance must be within 2.5 - 4.2 ohms.

8. Check the resistance of temperature compensating winding ℓ_2 . Measuring must be carried out between the

EC-25B rheostat contact pin to which common lead of windings ℓ_1 and ℓ_2 and the other lead of winding ℓ_2 unsoldered from resistor R_1 . The winding resistance must be within 1510 - 1770 ohms.

9. Check the resistance of paralleling winding S_0 between contact pins J and I which must be within 0.33 - 0.38 ohm.

Note: Resistance limits of the regulator windings are given for a temperature of $+20^\circ\text{C}$. If the temperature at which measurement is taken differs from that mentioned above, the resistance must be re-calculated relative to a temperature of $+20^\circ\text{C}$.

10. If resistances across the regulator windings are lower than those given above, it means that there are turn-to-turn short-circuits in the coil which in this case must be replaced as well as other defective elements of the circuit (for replacements, follow Section "Disassembly and Assembly of Regulator").

11. After replacement of defective elements, assemble the regulator in the order reverse to disassembly.

If defective elements are not detected in the course of external inspection, preliminary checking of the regulator operation and checking of the circuit elements or defective resistors have been replaced without complete disassembly of the regulator unit and disturbance of its adjustment (the regulator and carbon pile operate properly), subject such a regulator to testing according to Section D "Regulator Testing".

Additionally check the stability of the hot regulator operation by cutting the generator load in and out at maximum speed. At the same time, listen to the operation of the carbon pile through the earphones.

If variation of the regulated voltage exceeds 2.7 V and surpasses 26.5 - 30 V range or unstable operation of the regulator is noted (chattering or rattling is heard

in the earphones when the load is cut out), disassemble the regulator, check the armature and carbon pile. This done, assemble, adjust and test the regulator.

C. Disassembly and Assembly of Regulator

Before disassembling the regulator, remove and inspect the carbon pile (Fig.33), for which purpose:

1. Remove safety wire 27 and unlock adjusting screw 22 (Fig.15).

2. Install the regulator vertically with its flange upward and turn out adjusting screw 22. Insert a metal rod into the carbon pile opening and turn the regulator over so that the carbon discs fall out of the tube on the rod.

3. Inspect the carbon pile holding it as shown in Fig.34. During inspection do not remove the pile from the rod or touch the contact surfaces of the discs by hand. The discs must be shifted along the rod by grasping their outer edges.

When the number of fractures, split or burnt discs does not exceed 10, they may be replaced with new ones taken from the WP-9 pile, otherwise the whole pile must be replaced.

If burning of the carbon discs is not excessive and no spare piles for replacement of the discs are available, it is allowed to remove burnt spots by polishing the discs with the glass as it is instructed for polishing carbon contacts. When polishing the carbon discs, maintain their thickness within 0.8 ± 0.1 mm and see that their upper and lower bases are parallel (parallel misalignment not exceeding 0.02 mm is tolerable).

4. Check the condition of the carbon contacts on adjusting screw 22 and armature 7 (Fig.16). Remove burnt spots from the adjusting carbon contact by polishing with frosted glass. The working surface of the

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adjusting carbon contact is smoothed and polished by moving the frosted glass in circles while blowing off carbon dust.

5. Inspect the carbon contact on the armature through tube 13. In case the armature carbon contact is burnt, disassemble the regulator, take out the armature and remove the burnt matter in the same way.

If part of the contact projects less than 0.4 mm above the adjusting screw seat, replace such a contact.

When replacing the carbon contact, slightly crimp the holder seat so that the contact enters it with difficulty to ensure reliable fitting in the seat without, however, damaging the silver coating on the contact. After replacement of the carbon contact is over, polish its working surface.

6. Insert the carbon pile into the regulator as shown in Fig.35. Before inserting the carbon pile, carefully shake it and blow off dust.

1. Disassembly of Regulator for Replacement of Armature

The armature must be replaced in case of breakage, burnt contact of the armature, broken outgoing wires and other damages.

During operation permanent set of the armature springs may take place causing displacement of the operation point of the regulator adjustment and, consequently, reduction of the regulated voltage. When permanent set of the springs is noticed, adjust the regulator anew. As a rule replacement of the armature is not required.

To replace the armature, do the following (Fig.16):

1. Remove the carbon pile as instructed above.
2. Unsolder the wire running to the armature from terminal B cable shoe.

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3. Remove the BC-25B rheostat from disc 45 having previously turned out attaching screws.

4. Back out three screws 47 coupling the electromagnet case with the shaped bracket and replace the armature set.

Assembly of the regulator is the reverse order of disassembly.

Note: The armature must be replaced as a set only, i.e. replace armature, conical ring and annular gaskets. Some types of regulators may have no annular gaskets. When installing a new armature provided with annular gaskets, the latter must be installed. Solid brass gasket is not replaced.

2. Disassembly of Regulator for Replacement of Coil

To replace the coil, proceed as follows:

1. Turn out two screws fastening the BC-25B rheostat and remove it.
2. Remove the cover from the BC-25B rheostat.
3. Unsolder the wire running to the electromagnet coil from one cable shoe.
4. Unsolder the wires running to the electromagnet coil from the cable shoes of terminals I and II, temperature compensating resistor H3B-25-20 ohms and stabilizing resistor H3B-10-1500 ohms.
5. Turn out three screws coupling the electromagnet to the bracket.
6. Remove the cover with the core and take out the coil together with sealing gaskets.
7. Replace the coil and solder the leads to the cable shoes and circuit elements.

Solder the coil leads in the following way: beginning of first winding $K\ell_1$ - to the lead of resistor R_2 ; end of first winding $K\ell_1$ and beginning of second winding $H\ell_2$ - to the cable shoe of the BC-25E rheostat; beginning of third winding HS_0 - to the cable shoe of terminal A; end of third winding KS_0 - to the cable shoe of terminal T. If a spare coil is not available, rewind it according to the winding data given in Section II.

When rewinding the coil, insulate the windings and leads according to the coil descriptions and using a model made by the Manufacturer. Mark the leads of windings since faulty connection results in disturbance of the regulator normal operation.

8. Insert the coil into the electromagnet case and assemble the regulator in the order reverse to disassembly.

3. Disassembly of Regulator for Replacement of Insulating Tube

In case of puncture (burning through) of the duralumin insulating tube, replace the latter. The puncture may happen as a result of unskillful adjustment or incorrect operation (the regulator operated under "chatter" condition).

The puncture of the insulating tube can be detected by fluctuations of the regulator voltage or during its inspection (before inspection wipe the tube with dry soft cloth). In case of puncture damaged spots on the tube glossy surface are visible. Burnt-through spots at the edge of the tube on the armature side are mostly encountered.

Tubes with damaged insulation must be replaced with new ones.

To replace the insulating tube, proceed as follows:

1. Turn out screw 33 fastening the cable shoe with the wire running to terminal A and remove the cable shoe (Fig.15).

2. Unsolder the conductor running from the armature from terminal B.

3. Remove resistors $\Pi 9B-25-20$ ohms and $\Pi 9B-10-1500$ ohms from the lugs of the shaped bracket for which purpose turn out the attaching screws and nuts and remove gaskets and bushings insulating the temperature compensating resistor $\Pi 9B-25-20$ ohms.

4. Turn out two screws 2 and remove the BC-25E rheostat from the regulator.

5. Turn out three screws 4 attaching electromagnet 6 to shaped bracket 7 and remove the electromagnet.

6. Remove the shaped bracket with the finned cooler from the plate having previously turned out four counter-sunk screws attaching the bracket to the plate.

7. Turn out three nuts 13 attaching studs 11 to the finned cooler and having turned the studs out of the bracket, move the latter and protective cap 8 from the finned cooler.

8. Turn out screws 28 attaching flange 23 to the finned cooler and remove the flange together with insulating gaskets 29 and 24.

9. Press the duralumin insulating tube out of the finned cooler. To this end, install the finned cooler on a stand with an opening for the tube. Pressing out of the tube is shown in Fig.36. It is carried out on the side of the fin against which the protective cap rests.

The projecting end of the tube must be sunk flush with the finned cooler and then by means of a special rod whose diameter is somewhat less than the hole in the cooler the tube must be pushed out.

10. Press in a new duralumin insulating tube on the side of the fin to which the flange is attached. Prior to this operation, coat the tube outer surface with bake-lite varnish.

To ensure the pressing in one end of the insulating

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tube approximately for half of its length has a slide fit while the other end has a force fit, therefore, insert the tube with that end forward which offers no resistance. Then press in the tube by means of a press.

On the flange side the end of the tube must project up to 3 mm. This is achieved by placing a washer 3 mm thick.

Pressing in of the tube is shown in Fig. 37.

To protect the insulating coating of the tube face, place a textolite gasket between the press and the tube.

11. Install flange 23 (Fig. 15) and couple the finned cooler with bracket 7 by the studs having previously installed insulating gaskets 9 and protective cap 8 between the finned cooler and the bracket. The insulating washers, bushings and gaskets insulating the flange from the finned cooler and the latter from the studs must be installed on bakelite varnish with consequent drying at a temperature of 150°C during 2 hours.

To assemble the regulator, proceed as follows:

Install the bracket with finned cooler 10 on the plate so that the finned cooler is on the side of the terminals and fasten the bracket to the plate with four screws.

Couple electromagnet 6 with bracket 7 by three screws 4. When installing the armature, see that the conical ring is in correct position, i.e. its cone faces the armature. A solid brass gasket and annular brass gaskets (if present in the given regulator) must be installed under the conical ring.

Solder the armature lead to terminal B. Install temperature compensating resistor 17 with the insulating bushing and washers and stabilizing resistor 20 on regulator bracket 7.

Install the BC-25E rheostat on regulator disc 3 having fastened it by two screws 2 with washers.

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Screw cable shoe 31 with the conductor running from terminal A to the flange.

Insert the carbon pile and the adjusting contact screw.

D. Regulator Adjustment

It is recommended to adjust and test regulators with generators they operate for or with one of ICP generators, for example, with the ICP-3000M generator.

The present Section gives the procedure for adjustment and testing of regulators both for a ICP generator and an equivalent generator. Speed of the ICP generator is set directly by the speed indicator while that of the equivalent generator, by its field current.

When using the equivalent generator its operation conditions are set and checked by a corresponding field current measured with an ammeter connected into the generator field circuit.

Values of field currents corresponding to the generator various speeds at idle run or under load are given in Table 2.

Table 2

Equivalent Generator Field Currents

Generator speed	Generator field current at idle run, A	Generator field current at rated load, A
Minimum	2.5 - 2.8	4.7 - 6
Average	1.4 - 1.6	2.4 - 2.6
Maximum	0.9 - 1	1.4 - 1.6

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According to the given field currents of the generator at idle run make marks on a shunt rheostat of the electric motor driving the generator, which must correspond to minimum, average and maximum speeds of the generator. These marks are used at the initial stage of the regulator adjustment, since calculations based on the field current with the regulator out of adjustment are not correct as the generator voltage differs from the rated value.

1. Adjustment Procedure

Adjustment of the carbon-pile voltage regulator consists in equalizing of its electromagnetic and mechanical characteristics. As is known, the width of such a zone must to a certain extent overlap the carbon pile deformation which takes place with variation of the pressure necessary to create the required resistance of the pile.

In case of an ideal alignment of the characteristics the mechanical force acting upon the armature (difference between the armature springs pull and the carbon pile resilience) must be equal to the electromagnet pull at constant voltage in its winding throughout the operating range of air gaps between the armature and electromagnet, determined by the carbon pile deformation.

In this case the armature shift depending upon the above-mentioned deformation which is required to obtain the predetermined values of the carbon pile resistance (and, consequently, of pressures exerted upon it) would have taken place at one and the same constant voltage in the electromagnet winding and the accuracy of the generator voltage regulation would have been the best.

But despite the fact that the carbon pile deformation is not significant, practically there is no place

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for an ideal alignment of the regulator mechanical and electromagnetic characteristics even in such narrow zone. Therefore, with variation of the carbon pile required resistance the generator regulated voltage is somewhat changed.

The purpose of the regulator adjustment is to select such an operating zone for the armature air gaps which ensures minimum variation of the generator regulated voltage, i.e. the alignment of the regulator characteristics is the most favourable. At the same time proper operating stability must be ensured. Thus, during the adjustment it is necessary to set a certain air gap (within the operating range of gaps) between the armature and the regulator electromagnet. This is achieved by changing the position of the regulator adjusting screw the electromagnet core being set.

When adjusting the regulator, refer to the diagram given in Fig.38 which shows the dependence of the generator voltage upon the shifting of the adjusting contact screw. The curve in the diagram was taken when the regulator was connected to the generator according to Fig.30 by measuring the generator voltage at no-load condition with constant speed at each position of the adjusting screw, starting with the moment when the screw came in touch with the carbon pile. When the screw does not contact the carbon pile the generator field circuit remains open and the voltmeter connected across the generator terminals reads residual voltage. After the adjusting screw comes in contact with the carbon pile the generator field circuit closes and the generator voltage starts to rise when the screw is turned in.

Up to point A the voltage increases slowly, since at first turning in of the adjusting screw takes up gaps between the carbon discs, due to which pressure upon the carbon pile rises insignificantly and decrease of its resistance is negligible. Further turning in of the

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adjusting screw up to point A' brings a sharp increase in the generator voltage, then the rise of voltage slows down and after reaching its maximum value at point B the generator voltage starts to diminish gradually to point B' and then more sharply. Between points C and D the generator voltage practically does not change. After point D further turning in of the adjusting screw causes a sharp increase in the generator voltage as was the case at section A-A'.

At section A-A' further turning in of the adjusting screw considerably increases pressure upon the carbon pile as a result of which its resistance diminishes and the generator voltage increases. In this range the air gap between the armature and electromagnet is large and the electromagnet pull is less than the effort of the armature springs, therefore, the adjusting screw axial movement causes smaller displacement of the armature. This leads to deformation of the carbon pile, increase of the pressure exerted upon it which in turn is followed by decrease of the carbon pile resistance and rise of the generator voltage.

A considerable increase of voltage causes a corresponding increase of the electromagnet pull which becomes commensurable with the counteracting effort of the armature springs. Therefore, at section A'-B' axial shift of the adjusting screw when it is turned in is followed by approximately the same shift of the armature towards decreasing the air gap between the latter and the electromagnet, as a result the pressure exerted upon the carbon pile and its resistance practically do not change and the generator voltage remains approximately at a constant level.

At section B'-C the gap between the armature and the regulator electromagnet is not so large and with the gap decrease the electromagnet pull increases more than the

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counteracting effort of the armature springs. Then the equilibrium between these two forces (considering the carbon pile resilience) with a gradual diminishing of the gap is ensured only at decrease of voltage necessary to obtain a smaller pull of the electromagnet. Therefore, at this section the axial shift of the adjusting screw (when turned in) is followed by a larger shift of the armature due to which the pressure upon the carbon pile diminishes and its resistance increases which results in decrease of the generator voltage.

Practically the most part of B'-C section is occupied by a zone of unstable operation of the regulator when its armature "chatters". It was mentioned above that at this section with a decrease of the air gap the electromagnet pull increases more than the effort of the armature springs. Therefore, each impairing of the equilibrium as well as turning in of the adjusting screw causes sharp attraction of the armature of the electromagnet resulting in "break" of the carbon pile and, consequently, of the generator field circuit. When the field circuit is broken the generator voltage drops almost to zero. Due to this the electromagnet pull sharply decreases and the armature forced by the ultimately compressed springs shifts in the opposite direction and with the effort greater than that previously exerted upon the carbon pile compresses the latter.

As a result the generator voltage considerably increases and again the electromagnet attracts the regulator armature since its pull exceeds the counteracting effort of the springs. The process of fluctuations repeats and the armature "chatters".

The regulator operation in the "chatter" condition is given in Fig.39.

The "chatter" condition is permanently followed by breaks of the generator field circuit caused by break

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of contact between the carbon pile discs, which is extremely detrimental to the pile causing burning and damage of the carbon discs and contacts. Because of this it is essential for the regulator to rapidly pass the "chatter" zone when adjusting the regulator.

After point C which is the end of the zone of the generator unstable operation the generator voltage variation along entire section C-D is insignificant with turning in of the adjusting screw. This screw is the zone of the generator stable operation.

The most favourable equilibrium between the regulator mechanical and electromagnetic characteristics takes place at this section which ensures stability of the regulated voltage.

Thus, select the operating point for the regulator adjustment at this section somewhere at its middle part which corresponds to $1/2 \pm 1/8$ of a turn of the adjusting screw from point C which is the boundary between the "chatter" zone and zone of the regulator stable operation.

Beyond point D turning in of the adjusting screw is followed by a rapid increase of the generator voltage, since at this point the springs rest against the conical ring and prevent the armature from shifting towards the electromagnet. Therefore, when the screw is turned in pressure upon the carbon pile increases which leads to decrease of its resistance and increase of the generator voltage. At this section the screw shifts axially due to the carbon pile deformation.

2. Regulator Adjustment Procedure

After separate elements of the regulator are checked for proper operation and the regulator is checked for correct assembly, proceed with adjustment.

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- WARNING:**
1. If the regulator needs replacement of the carbon pile, insert a new pile into the regulator before adjustment. When inserting the carbon pile into the finned cooler tube, see that the carbon discs enter the tube easily (without jamming).
 2. During adjustment, turn the adjusting contact screw and the core gradually by small turns (except for the case when passing the zone of the regulator unstable operation).
 3. During adjustment it is not recommended to loosen the locking screws more than is necessary for turning of the adjusting screw or the electromagnet core. Otherwise, tightening of the locking screw may change the adjustment.
 4. After complete adjustment, tighten the locking screws of the adjusting screw and core completely and see that the regulated voltage is not changed.

To adjust the regulator, proceed as follows:

1. Make sure that the electromagnet core is in the initial position for adjustment. If necessary, set it properly.

In the initial position the surface of core 43 face (Fig.16) must be flush with the surface of electromagnet case 4. This position is marked during assembly at the Manufacturing plant by two dots punched opposite to each other on the core and the electromagnet case. Therefore, for setting the initial position by turning the core,

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align both points and see that the core projects beyond the electromagnet cover by 1 - 2 turns of the thread.

It should be noted that setting of the core into the initial position must be performed during assembly of the regulator, otherwise, an error may be made by a complete turn of the core. This error will be found out during voltage adjustment in the operating zone: the voltage will be considerably lower than the rated value if the core is turned in, and considerably higher if it is turned out through one turn as compared to the initial position.

If the regulator has not been disassembled, i.e., its core has not been shifted relative to the position marked with a red paint on the core and cover of the electromagnet at the Manufacturing plant, adjustment of the regulator may be started with the core in the given position.

Do not turn in the core more than through 45° as to its initial position, since it may break the brass gasket, reduce the air gap and hamper normal operation of the regulator.

2. Set the resistance of the BC-25E rheostat at approximately 4 ohms by means of the slide.

Note: For convenience of adjustment it is allowed to use the BC-25E rheostat installed on the panel. In this case, remove the rheostat mounted on the regulator and short-circuit the leads running to it.

3. Install the regulator on the terminal block of the panel.

4. Turn out the adjusting screw until complete loosening of the carbon pile is obtained.

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5. Start the generator at idle run and set the average speed.

6. Slowly turn in the adjusting screw watching the readings of voltmeter V_1 indicating the generator voltage and listening to the carbon pile operation through earphones T. When turning in the screw, follow the diagram shown in Fig.38.

7. When the regulator enters the zone of unstable operation ("chatter" zone) indicated by heavy clicks in the earphones, quickly turn in the adjusting screw to pass this zone and then stop turning in of the screw.

8. Set the generator voltage at 28 - 29 V by means of the regulator electromagnet core, for which purpose turn the core clockwise to decrease voltage and counter-clockwise to increase it.

9. Set the generator at maximum speed and determine point C denoting the end of the zone of the regulator unstable operation. For this purpose, it is necessary to enter the "chatter" zone indicated by clicks in the earphones by turning out the adjusting screw. Then start turning in the screw and note its position when the "chatter" zone ends (clicks in the earphones cease). The found position of the adjusting screw will correspond to point C.

As was mentioned above determining of the boundary of the regulator unstable operation zone must be carried out as fast as possible to prevent the pile carbon discs from burning.

10. Determine the width of regulator stable operation zone C-D, for which purpose continue to turn in the adjusting screw and note its position corresponding to point D after which the generator voltage will be notably increasing. The width of C-D zone must correspond to not less than $1/2$ of a turn of the adjusting screw (or not less than 0.25 mm of its axial shift).

11. Set the generator at average speed and set the adjusting screw in the position corresponding to the regulator operating range, for which purpose turn out the screw through $1/2 \pm 1/8$ of a turn from point C.

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12. Check the stability of the regulated voltage with the generator idle while changing its speed from minimum to maximum. For this purpose, stop the generator, then start it again and while setting in turn minimum, average and maximum speeds, note the generator voltage for each case by the voltmeter.

Variation of the generator voltage during this checking must not exceed 0.5 V.

13. If voltage changes by more than 0.5 V, turn out the adjusting screw slightly, approaching point C. At the same time it is necessary to maintain the minimum permissible distance from this point according to Para. 11 (1/2 - 1/8 of the screw turn).

When approaching the "chatter" zone (point C), accuracy of voltage regulation increases but along with this the regulator stability diminishes. When in operation, stability of the regulator is the most important and, therefore, during adjustment do not try to obtain accuracy higher than the required.

Having changed the position of the adjusting screw, check the voltage acceleration once more as instructed in Para. 12.

If voltage variation cannot be brought to 0.5 V, send the regulator for overhaul to replace armature, conical ring and gaskets.

14. With the generator at an average speed, set the voltage at 28.5 - 29 V by turning the regulator core clockwise to reduce the regulated voltage, or counter-clockwise to increase it. At the same time, check that the total current of the regulator windings at the given voltage is 0.96 - 1.05 A.

While turning the core, remember instructions given in Para. 1 which forbid its turning in through more than 45° from the initial position.

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15. With the generator at average speed and no-load check the limits of voltage variation controlled by the PC-25 B rheostat. For this purpose, turn the knob of the rheostat clockwise from its initial position to the stop. As a result the generator voltage must gradually increase by not less than 1 V.

Then, set the rheostat knob in the initial position and turn it counter-clockwise to the stop. As a result the generator voltage must decrease by not less than 3.5 V. When adjustment is over, set the rheostat knob to its initial position.

16. Check functioning of the paralleling winding: supply 0.2 V from the storage battery through the potentiometer to this winding with the plus to terminal J of the regulator terminal block and the minus to terminal F. The regulated voltage must drop by 1.5 - 1.8 V.

17. Carry out mechanical treatment of the regulator: remove the regulator from the adjustment panel, install it on the stand for treatment (See Diagram in Fig. 31) and supply 3600 closing pulses of 28.5 - 29.5 V to the electromagnet windings (through terminals B and E).

18. Install the regulator on the adjustment panel, check it and readjust, if necessary, in accordance with Para. 14.

19. Carry out final treatment of the regulator under current:

(a) carry out heat treatment during 1 hour with the generator field current within 3.5 - 4.5 A;

(b) with the generator at average speed cut in and off rated load for 1800 times (approximately 60 times per minute). For an equivalent generator set the speed and load so that the field current at load drop changes from 2.5 - 3 A to 1.2 - 1.8 A;

(c) warm up the regulator during 15 min. under the operating condition specified in Item "a".

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Note: Treatment of the regulator under current may be carried out on the adjustment panel or on a special panel similar to the above-mentioned but wired according to a simplified diagram. It is recommended to use such a panel with an equivalent generator.

20. Set the generator at a maximum speed and check according to Paras 9 and 11 position of the adjusting screw. If necessary, readjust the regulator (the screw must be turned in by $1/2 \pm 1/3$ of a turn from point C).

21. Check the regulator voltage variation according to Paras 12 and 13.

22. Set the level of regulated voltage at $29^{+0.3}_{-0.5}$ V with the generator at rated load. For this purpose, stop the generator, start it again with the load cut in and set the average speed (field current 2.4 - 2.6 A). Adjust the voltage by the RC-25B rheostat if its deviation from the above-mentioned level is below 0.5 V or by the core. In case the voltage duration exceeds 0.5 V adjust it with the RC-25B rheostat. When setting voltage, watch the current value in the regulator windings which must be within 0.96 - 1.05 (at 38.5 V).

23. Check the limits of voltage variation controlled by the RC-25B rheostat according to Para. 15.

D. Testing the Regulator

After adjustment of the regulator find its operating characteristics when it operates in conjunction with a T GP or equivalent generator.

1. Find parameters of a solid regulator, for which purpose:

(a) start the generator at idle run and set the minimum speed of rotation;

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(b) set the average speed of rotation;
(c) increase the generator speed to the maximum value;
(d) cut in and off rated load for three times;
(e) reduce the generator speed to the average value;
(f) set the minimum speed of rotation;
(g) record the values of the generator voltages measured when checking it according to Items "a" - "f".

Note: Checking of the regulator parameters according to Items "a" - "f" must be carried out approximately for 1 minute while the generator speed must be changed gradually.

2. Carry out heat run of the generator for one hour at the generator field current of 3.5 - 4.5 A.

3. Find the parameters of the hot regulator with the generator running at no-load according to Para. 1.

4. Measure the parameters of the hot regulator with the generator operating at rated load, for which purposes:

(a) with the generator at minimum speed, cut in rated load;
(b) set the generator at an average speed;
(c) increase the speed of rotation to the maximum value;
(d) cut in and off the load for three times;
(e) reduce the generator speed to the average value;
(f) set the minimum speed of rotation
(g) enter the generator voltage measured according to Items "a" - "f" into Table 3.

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Table 3

Nos	Condition of regulator	Variation of generator speed	Voltage at no-load, V			Voltage at rated load, V		
			generator speed			generator speed		
			min.	average	max.	min.	average	max.
1	Cold	Increase Reduction						
2	Hot	Increase Reduction						
3	Cold	Increase Reduction						

5. Remove the regulator from the panel and check resistance of its insulation when hot, which must be not less than 2 megohms. Resistance of the insulation is checked with a 500 V megger:

- (a) between the electromagnet case and contact pin E ;
- (b) between the electromagnet case and contact pin F ;
- (c) between contact pins E and F ;
- (d) between the electromagnet case and the finned cooler.

6. Cool down the regulator to the ambient temperature, find the parameters of the regulator at no-load when cold according to Para. 1 for the second time and compare them with the previously obtained data.

If corresponding voltages of the idle generator at average and maximum speeds before and after the heat run differ by not more than 0.3 V, the regulator is found completely treated.

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If the difference of voltage levels at corresponding speeds of rotation exceeds 0.3 V the regulator treatment is not completed. Such a regulator is subject to additional treatment under current (according to Para. 19, see page), readjustment and testing.

7. If the result is satisfactory, check voltage difference which should equal the difference between the maximum and minimum voltages (See Table 3).

The regulator test results may be considered satisfactory if the voltage difference does not exceed 2.7 V at generator speed changing within the given limits and load changing from zero to the rated value. Maximum voltage level should not exceed 30 V and its minimum value, 26.5 V.

If voltage acceleration does not exceed 2.7 V but the voltage level exceeds the specified limits (26.5 - 30 V) by not more than 0.4 V, the regulator is considered serviceable. The regulator voltage must be adjusted by the BC-25E rheostat and the latter must be checked after adjustment.

If voltage difference exceeds 2.7 V or necessary adjustment with the BC-25E rheostat exceeds 0.4 V, the regulator is subject to readjustment and repeated testing.

XIII. CHECKING BC-25E RHEOSTAT

Checking of the BC-25E rheostat must be carried out according to the following procedure:

1. External inspection. During external inspection of the BC-25E rheostat make sure that it has no defects impairing its operation. Check that the slide tightly fits the rheostat winding and that the winding former is in good condition.

2. Determining resistance of BC-25E rheostat. Determining resistance of the BC-25E rheostat is carried out with the help of a tester. Full resistance of the resistor is measured with the knob turned to the right as far as it will.

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go (by arrow HIGHER (BOLENE)) and must be within 5.7 - 6.3 ohms.

3. Checking resistance for smooth variation when the BC-25E rheostat knob is turned. Checking is carried out according to the diagram given in Fig. 40. Connect resistor R of 25 ohms in series with the BC-25E rheostat and voltmeter V with measuring range of 30 V to the BC-25E rheostat leads. Voltage of 24 - 30 V is supplied from a D.C. source.

When the BC-25E rheostat knob is turned, the voltage checked by voltmeter V must change smoothly without jumps or falls. The value of voltage with the knob turned counter-clockwise as far as it will go must be equal to zero. When the knob is turned clockwise to the stop, the voltage must be equal to approximately 5.5 - 6 V (when supplied voltage is 30 V).

If the BC-25E rheostat has defects it must be replaced with a good one.

XIV. SLUSHING AND STORAGE

The Manufacturing plant delivers regulators in an individual (designated for one set only) soft packing (made of corrugated cardboard) placed for the time of shipment in wooden boxes. During packing separate parts and units of the regulator set are not subjected to slushing.

For a long-term storage regulators are packed into a case together with a chemical moisture absorbent. Then the case is sealed by dipping it in a melted mixture consisting of paraffin and ceserine. When the mixture cools down, the upper layer of the case becomes moisture-proof. Note on slushing is made on the case label.

Boxes delivered on the Customer's storehouse must not be stored outdoors. It is allowed to open the boxes in closed premises only.

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Regulators must be stored unpacked on wooden racks in dry heated premises with ambient temperature from +5 to +25°C and relative humidity up to 70 per cent. It is permissible to store regulators in cardboard packing provided by the Manufacturing plant.

Sets of regulators subjected to slushing must be stored under the same conditions as regulators not subjected to slushing.

It is allowed to open such cases only for installing the regulator in an aircraft.

Appendix 1

TECHNICAL DESCRIPTION OF TYPE PC-2, PC-7,
EC-6000 and EC-12,000 BALLAST RESISTORSI. Purpose

Type PC-2, PC-7, EC-6000 and EC-12,000 ballast resistors are the elements of circuits of aircraft paralleled generators.

One ballast resistor is cut into the minus circuit of each generator and together with voltage regulators is used for automatic equalizing of load between the paralleled generators.

Equalizing of loads is obtained by automatic increasing or decreasing of voltage of appropriate generators.

Connection of the ballast resistors is shown in the key diagram given in Fig. 5.

For more detailed description of the ballast resistors operation, relevant pages.

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II. Specifications

Type of ballast resistor	Rated current, A	Ohmic resistance at ambient temperature of +20°C, ohms
PC-7	100	0.0043 ± 6%
EC-6000	200	0.00214 ± 6%
PC-2	300	0.00143 ± 6%
EC-12,000	400	0.00107 ± 3%

III. Design

The design of the ballast resistors is shown in Figs 41, 42, 43 and 44.

The main elements of the ballast resistors are nichrome plates 3 brazed to brass rods with a high-heat solder.

Note: The shape of the plates can be changed during the resistor adjustment within the area marked in contour and dashed lines.

The brass rods serve for connection of the ballast resistor to the generator lead and for attaching it to the aircraft structure.

Rod 2 is connected with the minus (earth) of the aircraft while rod 1 which is somewhat longer than rod 2 carries insulating bushing 8 and washer 7 serving for its insulation from the place where it is attached to the aircraft.

To connect the ballast resistors to the generator lead and to attach them to the aircraft strut or bulkhead, the coupling ends of brass rods 1 and 2 are provided with thread and nuts 4 locked with spring washers 5. To ensure better heat dissipation the brass rods are provided with ribs. Face of rod 1 is provided with screw M4 used for fastening the wire

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running from the regulator equalizing winding.

The table of specifications shows that value of the ballast resistors does not differ from the rated value by more than ± 5 per cent and in case of a EC-12,000 ballast resistor the variation does not exceed ± 3 per cent.

Such an accuracy is necessary to ensure more correct distribution of loads between the paralleled generators. It is obtained by adjustment (calibration) of resistance value. To increase the resistance it is necessary to reduce the width of the plates, as shown in Fig. 41.

All the markings of the ballast resistor (type, rated current, ohmic resistance with allowance, Manufacturer's trade-mark and ordinal number of the resistor) are punched on the rods.

IV. Installation and Operation of Ballast Resistors in the Aircraft

Before installation, check the ballast resistor mechanical damage (plates unsoldered from rods, cracks or chipping on the insulating washers and bushings).

The ballast resistors are mounted on the struts or bulkheads reliably connected with the common minus (earth) of the aircraft.

The rods of the resistors are inserted into holes in the bulkheads and secured with nuts 4. Long rod 1 to which wires from the generator minus terminal are connected is insulated from the aircraft structure by textolite washer 7 and bushing 3 while short rod 2 is directly fastened to the bulkhead and is electrically connected with the common minus (earth) of the aircraft. Make sure and see that connection between the ballast resistor and the aircraft earth is in good condition as load distribution between the paralleled generators depends upon the value of transient resist-

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ance in connections.

When fastening insulating washers and bushings be careful to avoid damaging them.

During operation the ballast resistors can be heated to a high temperature, therefore, locate them in such places where heat radiated by the resistors will not damage the equipment located nearby.

During the operation the ballast resistors need no special care but it is necessary to check the tightening of the nuts on the coupling rods and screw fastening the cable shoe of the equalizing wire.

Appendix 2

TECHNICAL DESCRIPTION OF TYPE TC-9A,
TC-9AM, TC-9A-12 AND TC-9AM-12 TRANSFORMERS

I. PURPOSE

Type TC-9A, TC-9AM, TC-9A-12 and TC-9AM-12 stabilizing transformers are designed to increase the operating stability of generators or starting generators operating in conjunction with carbon-pile voltage regulators, two or more paralleled generators operating with a storage battery, or one generator operating in parallel with a storage battery.

TC-9AM transformers differ from TC-9A transformers as well as TC-9AM-12 from TC-9A-12 only in overall dimensions and partially in winding data (See Table of Winding Data).

Selection of transformer, type TC-9A (TC-9AM) or TC-9A-12 (TC-9AM-12), depends upon the output of the serviced generators. The TC-9A (TC-9AM) transformers are designed for operation with ICP generators or with ICP-CT starting generators rated at 6 - 9 kW output.

The TC-9A-12 (TC-9AM-12) transformers are designed for operation with generators or starting generators rated at 12 kW output.

II. Specifications

A. Conditions of Operation

The transformers operate reliably under the following conditions:

1. Ambient air temperature from -60 to +50°
2. Altitude above sea level to 20,000 m.
3. Relative humidity of ambient air to 98 per cent
4. Vibration at attachment places with frequency from 20 to 30 c.p.s. and amplitude of 0.5 mm and with frequencies from 30 to 200 c.p.s. and amplitudes corresponding to proportionally increasing acceleration from 1.6 to 5 g

5. Jolting corresponding to conditions of landing and run of aircraft

B. Basic Specifications

1. Winding Data

Winding	Designation in diagram (Fig. 5)	Wire dia. w/o insulation, mm	Wire mark	Number of turns	Resistance at temperature of +20°C, ohms
1	2	3	4	5	6
<u>1. TC-9A transformer</u>					
Primary series winding	ℓ'	4.1x9.3	MTM	2 ^x	-
Secondary winding	ℓ ₁	0.69	Н9В-1	265	1.37±0.11
Equalizing winding	ℓ ₂	1.3	Н9В-1	65	0.165±0.015
Primary parallel winding	ℓ ₃	0.23	Н9В-1	1500	165±10
<u>11. TC-9AM transformer</u>					
Primary series winding	ℓ'	4.1x9.3	MTM	2 ^x	-
Secondary winding	ℓ ₁	0.69	Н9В-1	260	1.2±0.11
Equalizing winding	ℓ ₂	1.12	Н9В-1	65	0.15±0.015
Primary parallel winding	ℓ ₃	0.15	Н9В-1	1200	165±16 17

* One turn of the copper busbar should be counted for two as the copper busbar winds around the magnetic circuit twice. The leads of the second turn are closed outside the transformer.

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1	2	3	4	5	6
<u>III. TC-9A-12 transformer</u>					
Secondary winding	ℓ'_1	0.69	НЗВ-1	265	$1.37^{+0.11}$
Equalizing winding	ℓ'_2	1.3	НЗВ-1	88	$0.165^{+0.02}$
Primary parallel winding	ℓ'_3	0.23	НЗВ-1	1500	105^{+10}
<u>IV. TC-9AM-12 transformer</u>					
Secondary winding	ℓ'_1	0.69	НЗВ-1	260	$1.2^{+0.11}$
Equalizing winding	ℓ'_2	1.12	НЗВ-1	65	$0.15^{+0.015}$
Primary parallel winding	ℓ'_3	0.15	НЗВ-1	1200	165^{+16}_{-17}
2. Operating condition - continuous					
3. Weight of transformers:					
TC-9A			not exceeding 1.6 kg		
TC-9A-12			not exceeding 1.2 kg		
TC-9AM			not exceeding 1 kg		
TC-9AM-12			not exceeding 0.8 kg		

III. Design and Principle of Operation

The key diagram of the TC-9A (TC-9AM) and TC-9A-12 (TC-9AM-12) transformers connection is given in Fig. 22.

Each transformer has four windings: primary series winding ℓ'_1 (two power turns in TC-9A and TC-9AM transformers and wire in TC-9A-12 and TC-9AM-12 transformers), primary parallel winding ℓ'_3 , secondary winding ℓ'_1 and equalizing winding ℓ'_2 .

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Primary series winding ℓ'_1 of the transformer is connected to the generators feeder and passes the generator load current.

Primary parallel winding ℓ'_3 is connected in parallel with the generator field winding; the direct current flowing through the winding is proportional to the generator field current.

Secondary winding ℓ'_1 is connected in series with operating winding ℓ'_1 of the voltage regulator electromagnet.

Equalizing winding ℓ'_2 is connected in series with the circuit of the voltage regulator equalizing winding S_0 . The current flows through this winding only when the loads of the paralleled generators are not equal.

As was mentioned in Section V ("D. Stabilizing Devices") when the carbon-pile voltage regulator operates in conjunction with the aircraft generator, fluctuations of the generator voltage close to the rated value are noted at transients (sharp changes of generator speed or load drops) caused by the inertia of the system elements.

To reduce the value and duration of such fluctuations, i.e., to ensure better stability of the system a stabilizing transformer is connected into the circuit.

When the generator operates under the steady-state conditions when no changes in load and field currents occur, the transformer does not transmit power from the primary into the secondary circuit and its windings operate only as resistors of the corresponding circuits.

Under unstable operating conditions (at sharp changes in the generator speed or load and also at fluctuations of the system) current is changed in transformer primary windings ℓ'_1 (generator load current) and ℓ'_3 (alternating current induced by the e.m.f. of the field winding self-induction will flow through this winding at transients along with the component).

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This change of current induces in transformer secondary windings $\mathcal{L}'_1$ and $\mathcal{L}'_2$ corresponding e.m.f. their values depending upon the rate of current changes in the primary windings.

The winding connections are made so that the electromotive force induced in secondary winding $\mathcal{L}'_2$ always precludes changes of current caused by variation of the system parameters.

For instance, with an increase of the generator voltage (when the mains load drops) current in the circuit of regulator electromagnet operating winding $\mathcal{L}'_1$ rises and the electromotive force (induced in transformer secondary winding $\mathcal{L}'_1$ at the moment the current changes in primary series winding $\mathcal{L}'_1$) prevents this current from increasing, since it is added to voltage drop created in the secondary winding by the current of the regulator operating winding. This is the same as if the voltage regulator operating winding were supplied with somewhat lower voltage of the generator than that really existing at the given moment. As a result the possibility of voltage readjustment, i.e. its reduction below the required level is lessened.

With a decrease of the generator voltage (the load is on), when current in the circuit of the regulator electromagnet operating winding reduces and the electromotive force (induced in transformer secondary winding $\mathcal{L}'_1$) is subtracted from the voltage drop across this winding, the regulator operating winding is supplied with a voltage somewhat higher than the generator voltage at the given moment. This prevents voltage from excessive increase.

Similar influence is exerted on transformer secondary winding $\mathcal{L}'_1$ and primary parallel winding $\mathcal{L}'_3$, only in this case signal lagging and corresponding phase shift take place.

Variations in the load current of the paralleled generators change the voltage drop across the ballast resistors and the current intensity in the circuits of the regulator equalizing windings and, simultaneously, induce electromotive

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forces of corresponding value and direction in windings $\mathcal{L}'_1$ and $\mathcal{L}'_2$.

The transformer windings are so connected that the electromotive forces induced help to eliminate fluctuations of the regulated voltage and, consequently, fluctuations of the whole system.

Thus, at transients pulses directed to reduction of the range and number of the system fluctuations close to the steady-state value are induced in the transformer secondaries reducing the amplitude of voltage fluctuations at transients and completely excluding the possibility of self-fluctuations in the system.

IV. Design

The stabilizing transformers are of a core type with O-shaped magnetic system.

The upper part of the magnetic circuit made in the shape of a square rod is detachable. The lower part is II-shaped. The two parts of the magnetic circuit are built up of electrical steel laminations (3-21 in TC-9A and TC-9A-12 transformers and 3-330 in TC-9AM and TC-9AM-12 transformers), 0.35 mm thick. The laminations making up the stacks are braced by steel rivets.

The side thickened laminations of the stacks are made of sheet steel 3,1.5 mm thick in TC-9A and TC-9A-12 transformers and of duralumin 2 mm thick in TC-9AM and TC-9AM-12 transformers.

At the base of the II-shaped stack these laminations are bent out to form the lugs for fastening the transformer in the aircraft. The upper rectangular stack is placed on the lower II-shaped stack and both of them are braced with threaded studs, forming a closed magnetic circuit.

Primary series winding $\mathcal{L}'_1$ of TC-9A and TC-9AM transformers is a rectangular copper busbar which passes through the

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transformer opening twice thus making two turns. The copper busbar is insulated by adhesive glass tape coated with electro-insulating enamel 1201. Both ends of the busbar are flattened and provided with holes for fastening to terminal bolts M8x1.25 press-fitted into plastic blocks. The blocks are screwed to the lugs at the lower part of the magnetic circuit. Winding 2' of TC-9A-12 and TC-9AM-12 transformers constituting one turn is a power conductor connecting the generator with the aircraft mains. This conductor is passed through the opening of the magnetic circuit.

All the other windings of the transformer are wound around one common rectangular former made of plastic which is mounted on the detachable part of the magnetic circuit. The coils are impregnated with insulation varnish No. 447. The winding leads made of flexible multi-conductor wire are connected to the terminal bolts used for connection to the external circuit. The terminal bolts are press-fitted into the insulating blocks attached to the transformer magnetic circuit by two screws each.

The terminal bolts are marked A, X, H, and K. From above the terminals are covered with a metal casing having on the inside riveted textolite plates to prevent the casing from short-circuit with current terminals should the casing be casually crumpled.

For correct connection of the transformer into the power mains the side laminations of the magnetic circuit are provided with inscriptions MAINS (CETB) and GENERATOR (TEH). The minus terminal is fitted on the side lamination of the magnetic circuit which has the inscription MAINS.

The TC-9A and TC-9A-12 transformers are identical in dimensions and winding data and are assembled of identical parts and units. The only difference between these transformers is that the TC-9A-12 transformer has no current winding 2'. The same difference is between the TC-9AM and

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TC-9AM-12 transformers.

The TC-9AM and TC-9AM-12 transformers are of identical design but have smaller dimensions and weight as compared to the TC-9A and TC-9A-12 transformers as the magnetic circuit of the former transformers is made of electrical steel 3-330 having higher magnetic properties.

The overall and installation dimensions of the transformers are shown in Figs 45, 46, 47 and 48.

V. Installation of Transformers in the Aircraft

The transformers are installed in the aircraft in any position and fastened by their lugs with four bolts M5. When selecting the place for installing the transformers, follow the instructions given in Section II.

The transformers must be connected to the aircraft mains according to diagrams given in Figs 5 and 22.

When connecting the transformers, observe the following rules.

1. Transformers of the same type only must be used in one aircraft (for example, either TC-9A or TC-9AM, etc.).
2. The transformers may be connected to the generator feeder before the DMP-400A (DMP-400) relay or after it.

When connecting the TC-9A or TC-9AM transformers, the wire running from terminal "+" of the generator (when connected before the DMP-400A relay) or from terminal STORAGE BATTERY (BAT.) (when connected after the DMP-400A relay) must be connected to the transformer terminal on the side with inscription GENERATOR, while the wire running from the terminal with inscription GENERATOR of the DMP-400A relay (when connected before the DMP-400A relay) or the plus busbar of the aircraft mains (when connected after the DMP-400A relay) must be connected to the transformer terminal on the side having inscription MAINS.

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transformer opening twice thus making two turns. The copper busbar is insulated by adhesive glass tape coated with electro-insulating enamel 1201. Both ends of the busbar are flattened and provided with holes for fastening to terminal bolts M6x1.25 press-fitted into plastic blocks. The blocks are screwed to the lugs at the lower part of the magnetic circuit. Winding 2' of TC-9A-12 and TC-9AM-12 transformers constituting one turn is a power conductor connecting the generator with the aircraft mains. This conductor is passed through the opening of the magnetic circuit.

All the other windings of the transformer are wound around one common rectangular former made of plastic which is mounted on the detachable part of the magnetic circuit. The coils are impregnated with insulation varnish No. 447. The winding leads made of flexible multi-conductor wire are connected to the terminal bolts used for connection to the external circuit. The terminal bolts are press-fitted into the insulating blocks attached to the transformer magnetic circuit by two screws each.

The terminal bolts are marked A, E, H, and K. From above the terminals are covered with a metal casing having on the inside riveted textolite plates to prevent the casing from short-circuit with current terminals should the casing be casually crumpled.

For correct connection of the transformer into the power mains the side laminations of the magnetic circuit are provided with inscriptions MAINS (CETB) and GENERATOR (TEH). The minus terminal is fitted on the side lamination of the magnetic circuit which has the inscription MAINS.

The TC-9A and TC-9A-12 transformers are identical in dimensions and winding data and are assembled of identical parts and units. The only difference between these transformers is that the TC-9A-12 transformer has no current winding 2'. The same difference is between the TC-9AM and

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TC-9AM-12 transformers.

The TC-9AM and TC-9AM-12 transformers are of identical design but have smaller dimensions and weight as compared to the TC-9A and TC-9A-12 transformers as the magnetic circuit of the former transformers is made of electrical steel 3-330 having higher magnetic properties.

The overall and installation dimensions of the transformers are shown in Figs 45, 46, 47 and 48.

V. Installation of Transformers in the Aircraft

The transformers are installed in the aircraft in any position and fastened by their lugs with four bolts M5. When selecting the place for installing the transformers, follow the instructions given in Section II.

The transformers must be connected to the aircraft mains according to diagrams given in Figs 5 and 22.

When connecting the transformers, observe the following rules.

1. Transformers of the same type only must be used in one aircraft (for example, either TC-9A or TC-9AM, etc.).

2. The transformers may be connected to the generator feeder before the JMP-400A (JMP-400) relay or after it.

When connecting the TC-9A or TC-9AM transformers, the wire running from terminal "+" of the generator (when connected before the JMP-400A relay) or from terminal STORAGE BATTERY (BAT.) (when connected after the JMP-400A relay) must be connected to the transformer terminal on the side with inscription GENERATOR, while the wire running from the terminal with inscription GENERATOR of the JMP-400A relay (when connected before the JMP-400A relay) or the plus busbar of the aircraft mains (when connected after the JMP-400A relay) must be connected to the transformer terminal on the side having inscription MAINS.

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When connecting the TC-9A-12 or TC-9AM-12 transformers, the power conductor running from terminal "+" of the generator (or from terminal STORAGE BATTERY of JWP-400A relay) is inserted into the transformer opening on the side with inscription GENERATOR and passed further to terminal GENERATOR of the JWP-400A relay (or the plus busbar of the aircraft mains).

To insert the power conductor into the opening of the TC-9A-12 or TC-9AM-12 transformer it is allowed to split its magnetic circuit. For this purpose, remove the protective covers, turn out two nuts and take out the detachable part of the magnetic circuit together with the coil.

The power conductor section which passes through the transformer opening must be wrapped with electric cardboard or dymateen and fastened on both sides of the transformer with clamps.

When the detachable part of the magnetic circuit is reinstalled, tighten its nuts as far as they will go.

3. The TC-9A or TC-9AM transformers may be connected into the minus circuit, i.e. between the generator and ballast resistor.

In this case, terminal GENERATOR of the transformer must be connected with the ballast resistor, while terminal MAINS, with the minus terminal of the generator.

The TC-9A-12 or TC-9AM-12 transformers may be also connected into the minus circuit. In this case, the wire running from the ballast resistor is inserted into the transformer opening on the side with inscription GENERATOR and passed further to the minus terminal of the generator.

Note: When using TC-9A (TC-9AM) transformers in the circuit with starting generators it is not recommended to connect winding 1' into the minus branch of the load circuit, since this winding will create an additional resistance in the

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armature circuit of the starting generator when the latter operates as an electric motor.

4. The equalizing windings of the transformers (terminals H-K) and P-27 regulator (terminals I-J) may be connected in any sequence, but the direction of current in windings H-K and I-J must remain unchanged.

5. The transformer minus terminal must be securely connected to the aircraft structure.

During operation the transformer need no special care. Check periodically its tightening in the aircraft and tightening of nuts on external connection terminals. When defect is found, remove the transformer and replace it with a new one.

When the guaranteed service life of the transformers is expired, check them for breaks in the windings and short-circuits in the coil turns. For detection of breaks in the windings, use a tester for measuring resistance. In case of a break the tester will show infinity.

Detection of the short-circuited turns in any of the transformer windings by the value of resistance may be erroneous (if the number of short-circuited turns does not exceed 25 per cent), therefore it is necessary to determine the no-load current and transformation ratio as well.

The no-load current and transformation ratio must not exceed the limits tabulated below.

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Type of transformer	Transformation ratio		Maximum no-load current, A
	$\frac{U_2}{U_1}$	$\frac{U_3}{U_1}$	
TC-9A TC-9A-12	0.32±10%	5.5±10%	0.35
TC-9AM TC-9AM-12	0.24±10%	4.3±10%	0.4

If the transformation ratio and no-load current differ from the above-mentioned values, it means that there are short-circuited turns in the transformer.

If the no-load current and transformation ratio correspond to the required limits, the transformers may be installed in the aircraft again.

Checking is carried out according to the diagram given in Fig. 49.

No-load current of the transformer is determined by milliammeter mA when voltage of 10 V, 50 c.p.s. controlled by voltmeter V_1 is supplied to winding ℓ_1 (terminals "1" and "X").

The transformation ratio is calculated as ratio between voltage measured by voltmeter V_2 across transformer windings ℓ_2 and ℓ_3 and voltage supplied to winding ℓ_1 (the supplied voltage must equal 10 V, 50 c.p.s.).

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Appendix 3

DESCRIPTION OF T-1F TRANSFORMER

1. Purpose

The T-1F stabilizing transformer is designed to increase stability of the voltage regulator operation at transients.

Operation of the transformer servicing the regulator is described in Section V (D. "Stabilizing Devices"). The connection diagram of the transformer is given in Fig. 50.

II. Specifications

A. Conditions of Operation

The transformer is designed for operation under the following conditions:

1. Temperature of ambient air from -60 to +50°C
2. Altitude above sea level to 17,000 m.
3. Relative humidity of ambient air to 98 per cent
4. Vibration of attachment parts with frequency from 20 to 80 c.p.s. with acceleration of 4g
5. Short-time jolting with frequency from 40 to 100 shocks per min. with acceleration of 4g

B. Basic Specifications

1. Winding Data

Winding	Designation in diagram	Wire dia. w/o insulation, mm	Wire w/o insulation, mm	Number of turns	Resistance at temperature of +20°C, ohms
Low-resistance winding	ℓ_1	0.62	H37	200	0.47 $\begin{smallmatrix} +0.038 \\ -0.036 \end{smallmatrix}$
High-resistance winding	ℓ_2	0.12	H3B-1	3180	300 $\begin{smallmatrix} +36 \\ -34 \end{smallmatrix}$

2. Operating conditions continuous
3. Weight of transformer not exceeding 150 gr

III. Design

The design and overall dimensions of the transformer are shown in Figs 51 and 52.

The main parts of the transformer are the coil with two windings 1_1 and 1_2 wound on plastic former 12 and the magnetic circuit consisting of steel core 2 and steel clamp 1. The coil with the magnetic circuit is enclosed in rectangular steel casing 11 welded of sheet iron and attached to it by means of packing textolite gaskets 3 and 10.

To increase the insulation resistance and heat removal the space between the casing walls and elements of the transformer is filled with insulation matter (bitumen) 13.

On top the transformer body is covered with insulating ebonite panel 9 which has terminal 5 (NCT) and two holes A and X.

The in of winding 1_1 and out of transformer winding 1_2 are connected to terminal NCT. . . Hole A serves for passing conductor 8 running from the in of winding 1_2 while hole X for conductor 7 running from the out of transformer winding 1_1 .

IV. Installing the Transformer in the Aircraft

The T-1F transformer must be installed at a place where it is prevented from heating by nearby located devices and where the temperature does not exceed +50°C. The transformer is attached to strap 15 welded to casing 11 by means of screws 14.

Cable shoes 6 of conductors 7 and 8 must be connected with the corresponding terminal screws on the regulator terminal block (according to letter inscriptions), and terminal 5, with the aircraft mains minus by means of a conductor. It is necessary to ensure reliable connection of terminal 5 (NCT) with the common minus (earth) of the aircraft. Break of wires running from terminals 5 and 7 (X) causes sharp increase of the generator voltage and may bring the generator and other small electric power consumers out of action.

Break of the wire running to transformer terminal A may cause self-fluctuations of the generator voltage and current; this will not damage the generator, however, such a generator must be disconnected from the system of parallel operation.

V. Operation

During operation the T-1F transformers need no special care and are not subject to electric checking. During routine maintenance only tightening of nuts on the transformer terminals and condition of wiring must be checked. Since the T-1F transformer is of a non-stripping type, it is not subject to repair.

After expiration of the guaranteed service life the transformers must be checked for breaks or short-circuits in the windings. Breaks in the windings may be detected by measuring resistance with the help of a tester. In case of break the tester will show infinity resistance.

Precise determination of the short-circuited turns in the transformer windings is checked by its no-load current. No-load current I_{n-1} is checked according to the diagram given in Fig. 53.

Primary (high-resistance) winding 1_2 of the transformer (terminal EIC and lead A) is supplied with 100 V A.C., 50 c.p.s. (measured by a voltmeter or tester) while the current consumed by the transformer is checked by an astatic milliammeter.

The no-load current must not exceed 0.26 A. If the current exceeds the above value, it means that short-circuited turns are present in one of the transformer windings. After checking up the transformers may be installed in the aircraft again.

Appendix 4

INSTRUCTIONS ON IMPREGNATING, VARNISHING
AND DRYING OF P-27 REGULATOR COILS

I. Material

1. Insulation varnish No. 447.
2. Electroenamel 1201.

II. Equipment

1. Vacuum impregnating installation.
2. Drying cabinet with air circulation, $t=105 - 115^{\circ}\text{C}$.

III. Technological Procedure

Nos	Operation	Temperature, $^{\circ}\text{C}$	Vacuum in mm of mercury or pressure in kg/cm^2	Time hr	Description of operation
1	2	3	4	5	6
1	Heating and drying in autoclave	70 - 80	1 kg/cm^2	2	Place coil in autoclave, close the autoclave cover and fasten it with wing bolts. Switch on electric heat- er. Cook in the cover must be opened
2	Vacuum drying of coils in auto- clave	70 - 80	700 - 720 mm of mercury	2	-
3	Sucking of varn- ish into autoclave till coils are com- pletely coated	-	-	-	(a) 0.5 hr before drain- ing varnish switch off electric heat- er (b) when draining varn-

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1	2	3	4	5	6
					ish check its level through inspection glass. Do not allow the varnish level to drop below outlet pipes (c) when filling is completed, eliminate vacuum and close the air outlet valve on the cover. Switch on the compressor and raise pressure in the autoclave to $2 - 4 \text{ kg/cm}^2$
4	Keeping coils in varnish	$2 - 4 \text{ kg/cm}^2$	5 min.		
5	Removal of pressure	1 kg/cm^2	5 min.		Open the cock on the autoclave cover
6	Repeat operations 4 and 5 for three times				
7	Draining of varnish from the autoclave to storage tank	-	~ 0.5		Open the cock on the autoclave cover
8	Pumping out of surplus varnish by means of vacuum-pump	$700 - 720 \text{ mm of mercury}$	~ 0.5		
9	Secondary draining of varnish		~ 0.5		After secondary draining of varnish, switch on electric heater

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1	2	3	4	5	6
10	Heating of coil in autoclave	$70 - 80$	1 kg/cm	1	The cock in the autoclave cover must be opened
11	Vacuum drying of coils in autoclave	$70 - 80$	$700 - 720 \text{ mm of mercury}$	3	
12	Removal of coils from autoclave	-	-	-	
13	Drying of coils in drying cabinet	$105 - 115$	-	24	
14	Coating of accessible parts of coils with electrocoat enamel 1201				
15	Drying of coils in drying cabinet	$105 - 115$		1	
16	Checking				(a) external inspection (b) check the insulation resistance of hot coils by a 500 V megger. Resistance must be not less than 100 megohms at a temperature of $85 - 90^\circ\text{C}$

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Appendix 5SPECIFICATIONS OF THE SET OF MAINTENANCE PARTS
FOR MAJOR REPAIR OF TWENTY P-27 VOLTAGE REGULATORS

Nos	Spare part	Dwg No.	Figure No.	Reference No.	Quantity per set
1	Resistor	119B-25-20 ohms	16	26	3
2	Resistor	119B-10-1500 ohms	15	20	3
3	Carbon pile	119P-9	16	12	8
4	Contact	745024	16	22	2
5	Nut	M4 11H 3-5	15	13	3
6	Screw, special	462514	18	9	80
7	Contact	746026	17	12	2
8	Washer	481500	16	17	2
9	Armature	670044	17	-	1
10	Gasket	308228	16	5	2
11	Gasket	380622	16	35	2
12	Gasket	388392	16	35	2
13	Nut, self-locking	1125A50-5	18	3	40
14	Washer	234A50-0.0-4-10	16	41	40
15	Nut, self-locking	1125A50-4	18	11	40
16	Screw	1323051-5-20	18	2	2
17	Washer	137A50-5	18	10	3
18	Spring washer	15A49-5	18	7	3
19	Lock nut	M5 11H 3-6	18	1	2
20	Screw	M3X6 11H 2-23	15	33	2
21	Washer	234A50-0.5-3-8	15	32	6
22	Spring washer	15A49-4	15	12	5
23	Spring washer	15A49-3	16	18	5

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Appendix 6LIST OF TOOLS USED FOR DISASSEMBLY
AND ASSEMBLY OF P-27 REGULATORI. Standard Tools

1. Pliers, L=125 mm
2. Screw-driver, L=200 mm
3. Forceps
4. Electric soldering iron
5. Brush No.10
6. Hair brush for flux
7. Cutters, L=125 mm
8. Shears
9. Hand-operated press
10. Socket wrench, b=5
11. Socket wrench, b=7
12. Socket wrench, b=9

II. Special Tools

1. Screw-driver for core
2. Rod for removal and installation of the carbon pile
3. Washer
4. Pin

III. Auxiliary Material

1. Frosted glass
2. Textolite A, sheet, electrical, 10 mm thick
3. Wire K0, dia. 0.8
4. Ethyl alcohol, raw
5. Flux (50 per cent mixture of pine colophony and raw ethyl alcohol)
6. Nitroenamel 1201
7. Solder, H00-40

8. Tin, 02
9. Colourless varnish AB4 for screws with 10 per cent addition of red enamel AM
10. Vinylchloride pipe, inner dia 3.5, 5 mm
11. Bakelite varnish A
12. Varnished silk MM 2, 0.1 mm thick
13. Electric cardboard 3BH, 0.2 mm thick
14. Electric cardboard 3BH, 0.1 mm thick
15. Silk sleeve, inner dia. 1.5 mm
16. Wire N3M, 0.09 mm in dia.
17. Wire H3B-2, 0.59, 0.74 mm in dia.
18. Wire MFCX 0.35 mm², 0.5 mm², 1.25 mm² in section
19. Varnished silk MMHC, 0.06 mm thick
20. Wire TM-200, 1.5 mm² in section
21. Wire 5HBM, 0.75 mm² in section

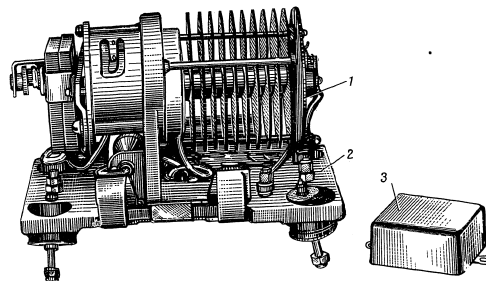


Fig. 1. P-27 Regulator Set. External View
1 — regulator with BC-25B rheostat; 2 — shock absorbing panel;
3 — KBM-31 capacitor (4 pF).

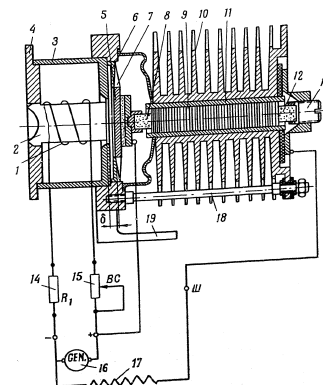


Fig. 2. Diagram of Simplified Carbon-Pile Voltage Regulator
1 — operating winding; 2 — core; 3 — electro-magnet case; 4 — electromagnet cover; 5 — armature; 6 — duralumin conical ring; 7 — armature springs; 8 — armature carbon contact; 9 — carbon pile; 10 — lined cooler; 11 — insulating tube; 12 — adjusting screw carbon contact; 13 — adjusting screw; 14 — temperature compensating resistor; 15 — adjustable resistor; 16 — generator field winding; 17 — generator; 18 — stud; 19 — shaped bracket; 20 — air gap.

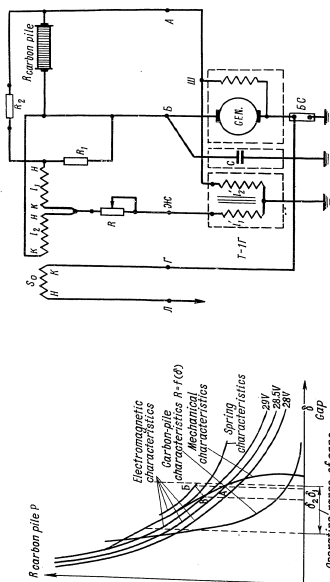


Fig. 3. Regulator Characteristics

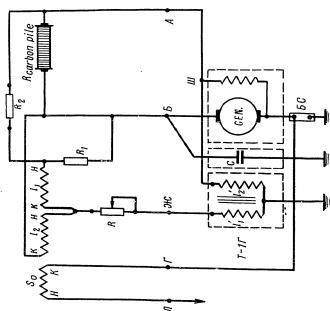


Fig. 4. Key Circuit Diagram of P-27

I_1 — regulator operating winding; I_2 — temperature compensating winding; S_0 — equalizing winding (parallel winding); R_{sp} — carbon pile; R_0 — temperature compensating resistor; R_2 — stabilizing resistor; R — adjustable resistor (rheostat); T-I — stabilizing transformer; I_1 and I_2 — stabilizing transformer windings; C — capacitor (4nF); Gen. — aircraft generator; H — beginning of winding; K — end of winding; A, B, r_1 , r_2 , J — contact terminals.

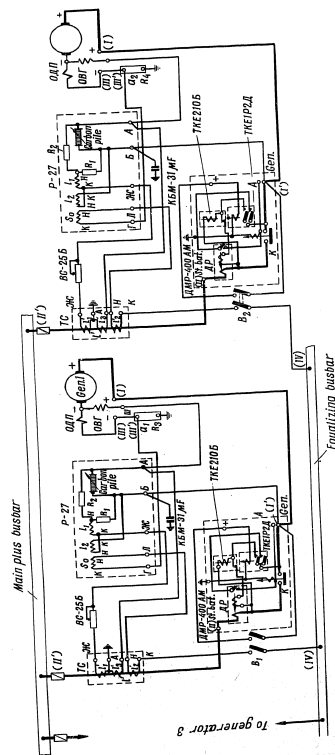


Fig. 5. Circuit Diagram of Paralleled Generators

Fig. 5. Circuit Diagram of Paralled Generators

201F—generator field winding; **C10H**—winding of secondary capacitor; **TC9A-12**—transformer winding of equalizing poles; **a**, **a'**—points for connection of equalizing windings at ballast resistor; **1**, **2**—terminals of generator; **3**—generator winding; **4**—regulator winding; **5**—regulator compensating winding; **6**—winding for resistance compensating resistor; **7**—winding for resistance compensating resistor; **8**—stabilizing winding; **9**—winding for connecting generator field winding resistor; **f**, **g**, **h**, **a**, **b**, **c**, **d**, **e**, **f**, **g**, **h**—two-pole switches for connecting generator to aircral mains.

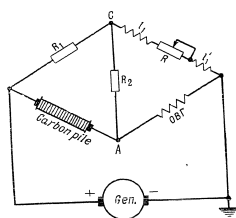


Fig. 6. Diagram of Stabilizing Resistor Operation

OBF — generator field winding;
R — rheostat resistance; R₂ — temperature compensating resistor;
R₂ — stabilizing resistor; I₁ — regulator operating winding; I₂ — transformer low-resistance winding.

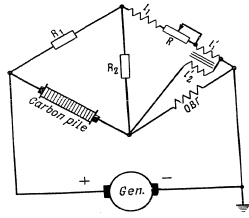


Fig. 7. Diagram of Stabilizing Transformer Operation

OBF — generator field winding;
R — rheostat resistance; R₂ — temperature compensating resistor;
R₂ — stabilizing resistor; I₁ — regulator operating winding;
I₂ — transformer low-resistance winding; I₂' — transformer high-resistance winding.

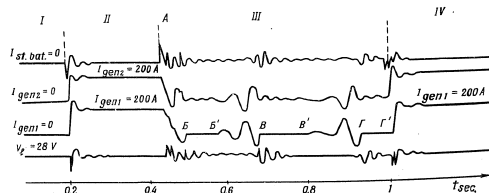


Fig. 8. Operation of Two FCP-CT-6000A Generators in Conjunction with 12CAM-28 Storage Batteries at Transients with Generators Speed Equal to 9000 r.p.m.

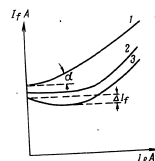


Fig. 9. Adjusting Characteristics of Generator at Constant Voltage and Maximum Speed of Rotation

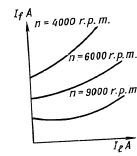


Fig. 10. Adjusting Characteristics of FCP-CT-6000A Starting Generator at Minimum, Average and Maximum Speeds of Rotation

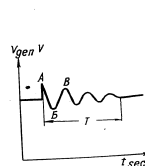


Fig. 11. Generator Regulated Voltage Variation when Operating in Conjunction with Carbon Regulator when Load is Cut Out

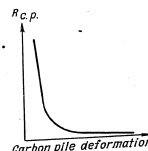


Fig. 12. Variation of Regulator Carbon-Pile Resistance Depending upon Shifting of Armature

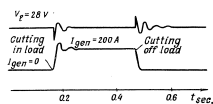


Fig. 13. GCP-CT-6000A Generator Operating in Conjunction with Carbon-Pile Voltage Regulator at 9000 r.p.m. when Load Is Cut In and Out (without storage battery)

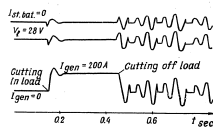


Fig. 14. GCP-CT-6000A Generator Operating in Conjunction with Carbon-Pile Voltage Regulator and 12CAW-28 Storage Battery when Load Is Cut In and Out (generator speed being 9000 r.p.m.)

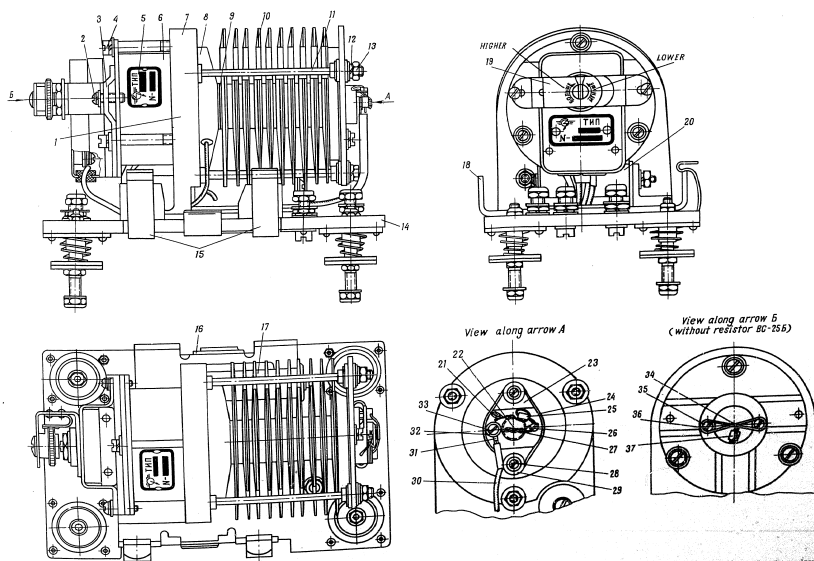


Fig. 15. P-27 Voltage Regulator

1 — regulator; 2 — screw; 3 — disc for installing external resistor; 4 — screw; 5 — trade mark; 6 — electromagnet; 7 — shaped bracket; 8 — cap; 9 — insulating gasket; 10 — finned cooler; 11 — stud; 12 — spring washer; 13 — nut; 14 — terminal block; 15 — hinge; spring lock; 16 — ball; 17 — temperature compensating resistor R_t ; 18 — plate; 19 — external resistor R (rheostat BC-25B); 20 — stabilizing resistor R_s ; 21 — hole for safety wire; 22 — adjusting screw; 23 — flange; 24 — insulating gasket; 25 — lead seal; 26 — screw; 27 — safety wire; 28 — screw; 29 — insulating washer; 30 — wire; 31 — cable shoe; 32 — washer; 33 — screw; 34 — safety wire; 35 — washer; 36 — screw; 37 — lead seal.

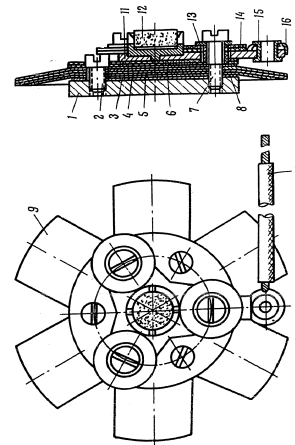


Fig. 17. Regulator Armature
 1 - disc; 2 - screw; 3 - brass gasket; 4 - brass gasket; 5 - washer;
 6 - insulating gasket; 7 - screw; 8 - ceramic bush; 9 - screw;
 10 - hollow rivet; 11 - hollow rivet; 12 - washer; 13 - insulating
 washer; 14 - hollow rivet; 15 - special washer; 16 - special washer.

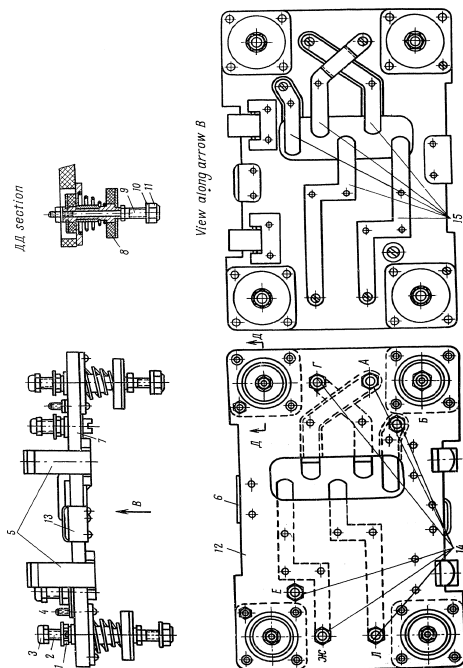


Fig. 18. Terminal Block (left-hand)
1 — lock nut; 2 — screw; 3 — self-locking nut; 4 — screw; 5 — locking spring; 6 — bail;
7 — spring; 8 — shock absorber; 9 — stud (special screw); 10 — washer; 11 — nut;
12 — block base; 13 — stop; 14 — terminal screw; 15 — contact plate.

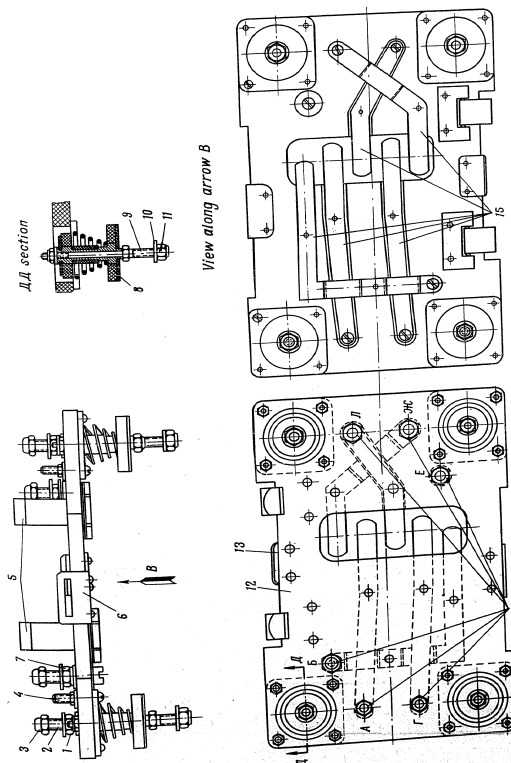


Fig. 19. Terminal Block (right-hand)
(Reference Nos same as in Fig. 18).

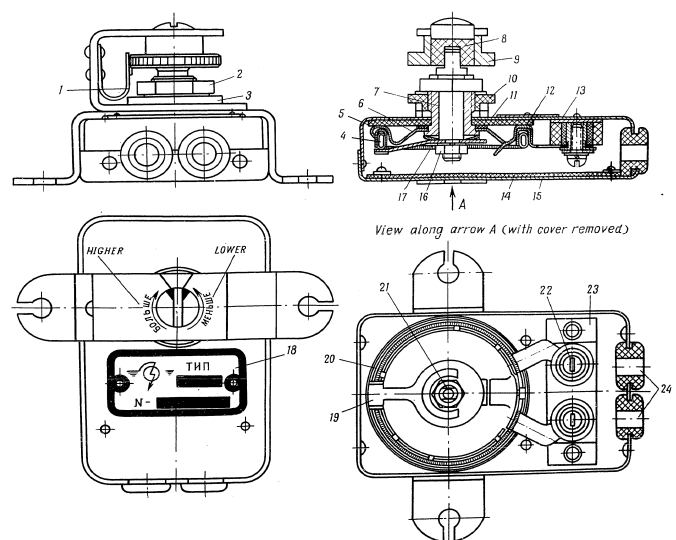


Fig. 20. External Resistor BC-255

1 — spring lock; 2 — nut; 3 — bracket; 4 — resistor frame; 5 — insulating gasket; 6 — casing; 7 — bushing; 8 — plastic insulation; 9 — knob; 10 — insulating bushing; 11 — housing; 12 — insulating washer; 13 — insulating gasket; 14 — insulating gasket; 15 — cover; 16 — nut; 17 — spring washer; 18 — trade mark; 19 — side; 20 — wire-wound resistor; 21 — axle; 22 — screw; 23 — terminal plate; 24 — rubber bushing.

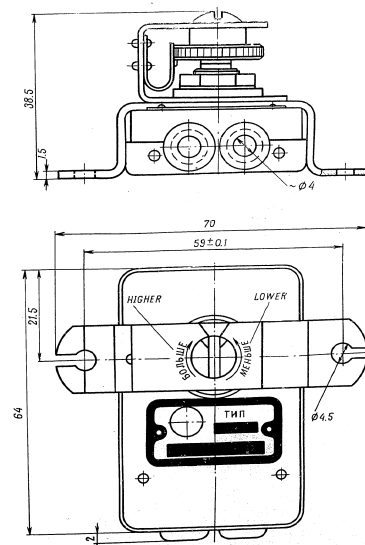


Fig. 21. Overall Dimensions of BC-255 External Resistor

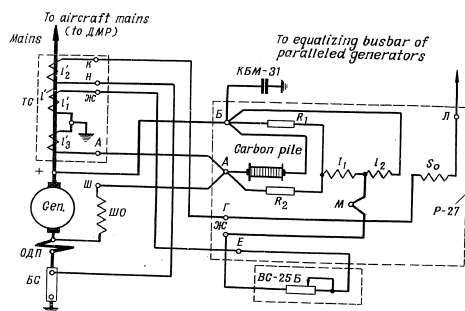


Fig. 22. Connection of P-27 Regulator when Using Terminal E

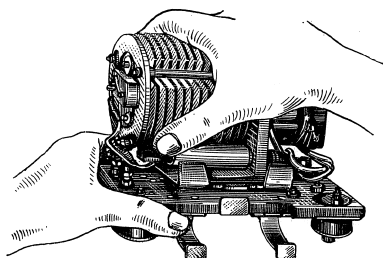
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Fig. 23. Engaging Regulator Plate Tenon into Terminal Block Bail

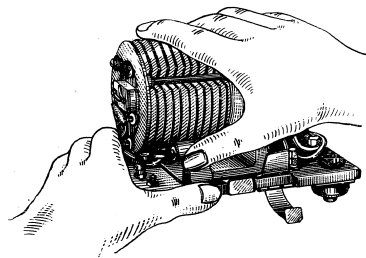


Fig. 24. Engaging Terminal Block Locks by Regulator Plate Uprights

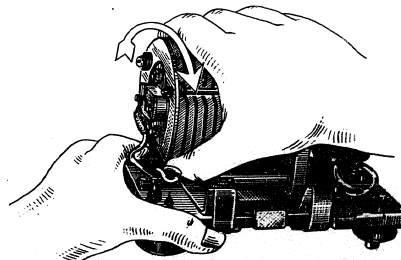


Fig. 25. Checking Regulator for Secure Installation on Terminal Block

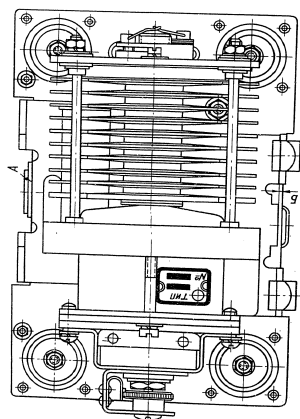


Fig. 28. Checking Regulator for Correct Installation

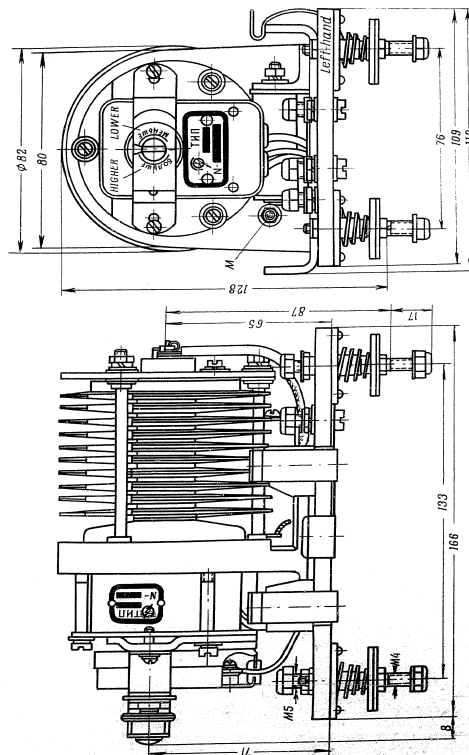


Fig. 27. Overall Dimensions of P-27 Regulator with Shock Absorbing Panel (left-hand)

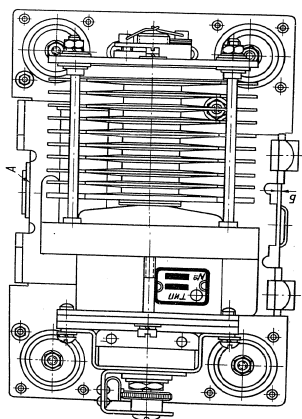


Fig. 26. Checking Regulator for Correct Installation

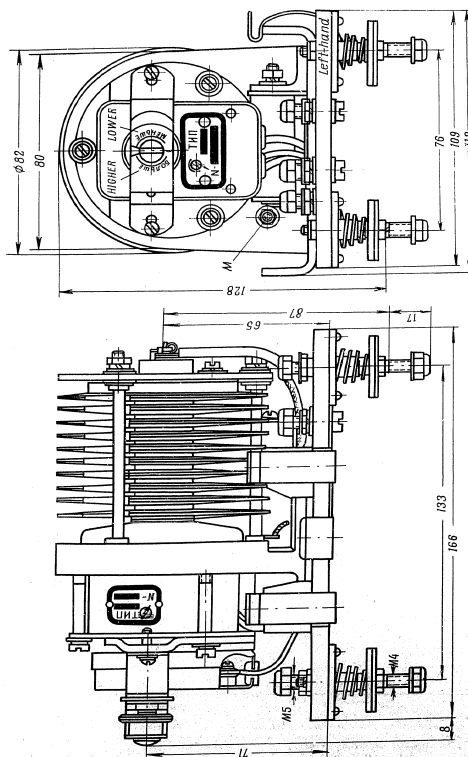


Fig. 27. Overall Dimensions of p-27 Regulator with Shock Absorbing Panel (left hand)

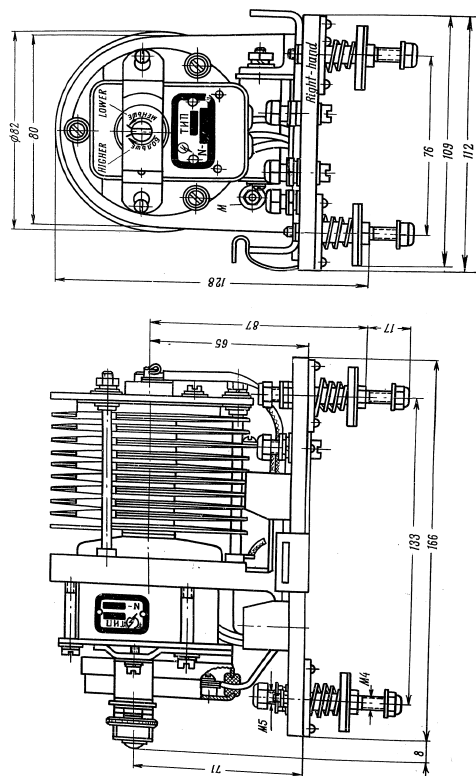


Fig. 28 Overall Dimensions of P-27 Regulator with Shock Absorbing Panel (right-hand)

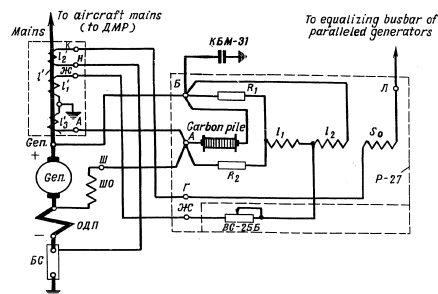


Fig. 29. Connection of P-27 Voltage Regulator with Transformers TC-9

V—primary series winding (two copper power turns in transformers TC-9A or TC-9AM and one turn made by power wire passing through opening in transformer TC-9A-12 or TC-9AM-12); V_1 —primary paralleling winding; V_2 —secondary winding; V_3 —equalizing winding; W —shunt winding; W_1 —winding of commutating poles; BC —ballast resistor; P-27—voltage regulator; A, B, F, J, K, L—voltage regulator terminals; I_1 , I_2 , S_1 —regulator windings; R_1 —temperature compensating resistor; R_2 —stabilizing resistor; $BC-255$ —external resistor; K6M-31—capacitor.

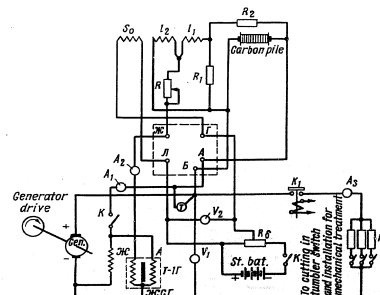


Fig. 30. Circuit Diagram of Panel for Testing Regulator

A, B, F, J, K, L—regulator terminal block terminals; Gen.—ICP-3000M or equivalent generator; V_1 —voltage checking generator voltage; V_2 —voltage checking voltage in paralleling winding; A_1 —ammeter checking generator field current; A_2 —ammeter checking current in regulator operating and compensating windings; A_3 —ammeter checking generator load current; R_1 —rheostat; K—tumbler switch; R_2 —load rheostat; R_3 —load switching resistor; T-1F—stabilizing transformer; T—earphones; I_1 —regulator operating winding; I_2 —regulator temperature compensating winding; S_1 —temperature compensating resistor; S_2 —regulator paralleling winding; R_4 —stabilizing resistor; R—adjustable resistor (BC-255 rheostat).

Fig. 35. Installing Carbon Pile

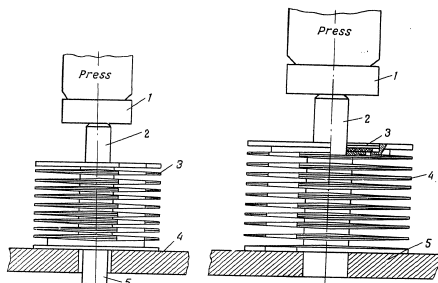


Fig. 36. Pressing-Out of Bushing

1—textolite gasket; 2—pressing-out pin; 3—finned cooler; 4—press base; 5—bushing.

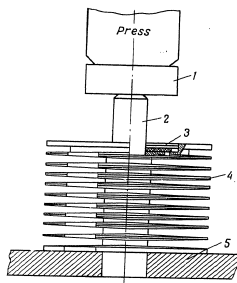


Fig. 37. Pressing-In of Bushing

1—textolite gasket; 2—bushing; 3—finning washer; 4—finned cooler; 5—press base.

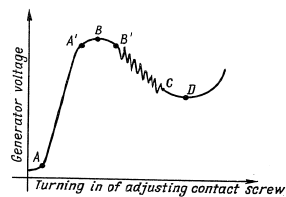


Fig. 38. Adjusting Curve

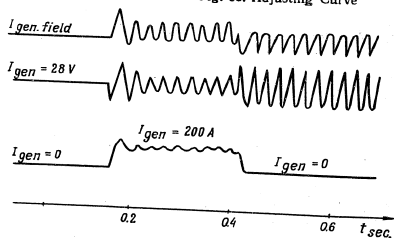


Fig. 39. Regulator Operation in "Chatter" Condition

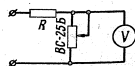


Fig. 40. Diagram for Checking BC-25B Resistor

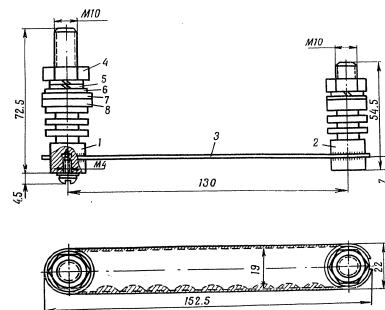


Fig. 41. Ballast Resistor PC-7

1—rod; 2—rod; 3—resistor plate; 4—nut; 5—spring washer; 6—plain washer; 7—insulating washer; 8—insulating bushing.

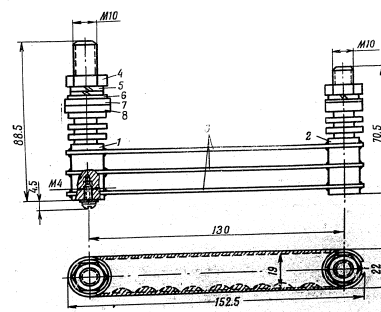


Fig. 42. Ballast Resistor PC-2

1—rod; 2—rod; 3—resistor plate; 4—nut; 5—spring washer; 6—plain washer; 7—insulating washer; 8—insulating bushing.

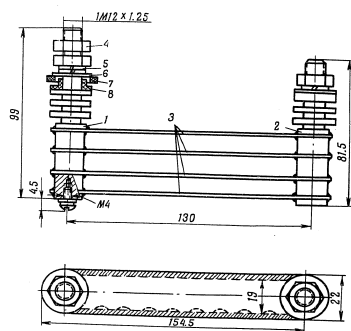


Fig. 43. Ballast Resistor EC-12000
(Reference Nos same as in Fig. 42).

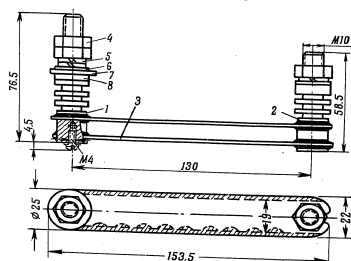
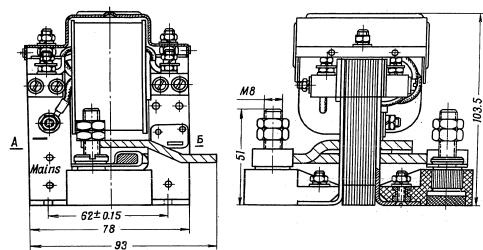


Fig. 44. Ballast Resistor EC-6000
(Reference Nos same as in Fig. 42).



A-B section

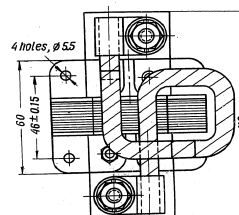


Fig. 45. Overall and Installation Dimensions of TC-9A Transformer

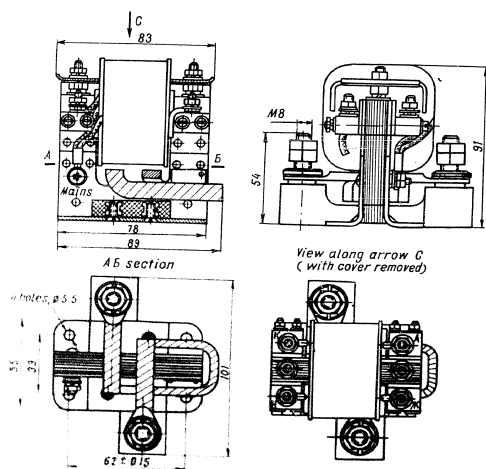


Fig. 46. Overall and Installation Dimensions of TC-9AM Transformer

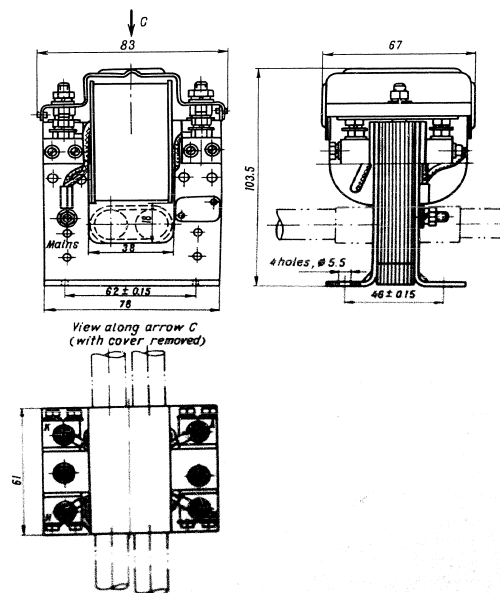


Fig. 47. Overall and Installation Dimensions of TC-9A-12 Transformer

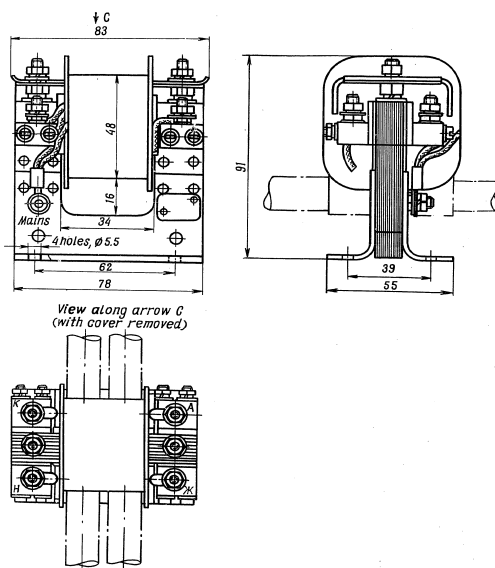


Fig. 48. Overall and Installation Dimensions of TC-9AM-12 Transformer

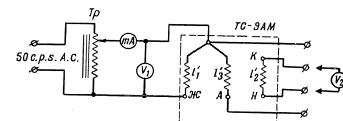


Fig. 49. Diagram for Checking TC-9A, TC-9AM, TC-9A-12 and TC-9AM-12 Transformers

TC-9AM — transformer to be checked; T_0 — laboratory adjusting transformer JIATP-2, mA—500 mA astatic milliammeter; V_1 and V_2 — A.C. voltmeters of TT-2 tester with 10—50 V measurement range.

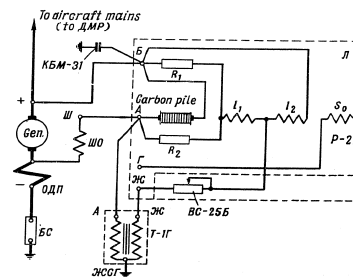


Fig. 50. Connection of T-1F Transformer with P-27 Voltage Regulator

OJH — winding of generator commutating poles; W — generator shunt winding; T-1F — stabilizing transformer; P-27 — voltage regulator; BC-255 — external resistor; A, B, F, K, J — P-27 regulator terminals; I_1 , I_2 , I_3 — P-27 regulator windings; R_1 — temperature compensating resistor; R_2 — stabilizing resistor; JCF — terminal of T-1F transformer; A, K — transformer leads.

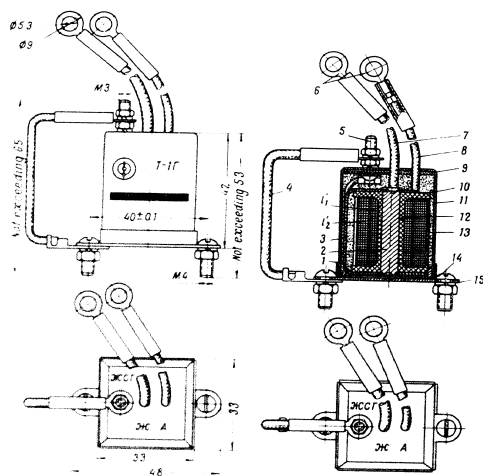


Fig. 51. Overall Dimensions of T-1F Transformer

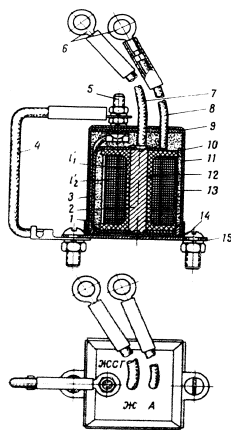


Fig. 52. Stabilizing Transformer T-1F

1—clamp; 2—core; 3 and 10—parking gaskets; 4—connecting conductor; 5—terminal; 6—cable shoe; 7 and 8—conductors of leads; 9—insulating panel; 11—casing; 12—coil former; 13—insulating material (dibutyl); 14—screw; 15—strap, P_1 and P_2 windings.

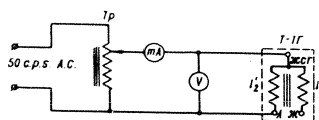


Fig. 53. Diagram for Testing T-1F Transformer

T-1F—transformer to be checked; T₂—laboratory adjusting transformer; ATP-2; mA—500 mA astatic milliammeter; V—A.C. voltmeter of tester TT-2 with 250 V measurement range.

Secret

IB-303 GUN ARMAMENT SURVEY

DESCRIPTION

Part II

939c

2
Secret

Copy No. 1

HL-100 (S-A-299) GUN ARMAMENT SYSTEM

DESCRIPTION

PART II

SECTION 1

ELECTRICAL UNIT

The tail gunner in the AH-12 aircraft aims the M10-55A sighting set at a target manually.

The gun of the M10-55Y turret is aimed at the same target following the sighting set motion by means of electrical units which are divided into the following groups:

1. Electrical machines (motor-generator unit, relay motors, relays)
2. Amplifier, amplifier unit
3. Fire control units
4. Control and check equipment.

1. ELECTRICAL MACHINES

- 1.1. Motor-generator unit

1.1.1. Motor

The MA-1, motor-generator unit is used to generate power and supply power to drive the electrically operated turret in flight.



Fig. 1. Motor-generator unit

The EA-3M motor-generator unit consists of the MSA-3 electric motor and two IEA-3M generators joined to the latter; the generators have the indices "1" and "2".

Each IEA-3M generator is provided with two control windings and one series winding. The control windings are supplied through the V-2M-1M magnetic amplifier.

The control windings are intended for changing polarity and value of voltage on the generator armature terminals, i.e. for reversing the drive electric motor connected to the generator terminals and for adjusting the motor speed.

The series winding compensates for a voltage drop in the motor-generator circuit due to change in load.

The common ventilation system is used for the generators and motor.

Self-ventilation is ensured by the centrifugal exhaust fan installed on the motor shaft.

Air for cooling is sucked through holes in the generator and escapes through the ports in the motor and housing assembly.

NOTE: To ensure the generators operation at altitudes exceeding 12,000 m. (if the generator is located outside the pressurized cabin) they are additionally cooled by ram air at a pressure of 200 mm.W.C. Ram air is supplied through the hose connected to the branch pipe located on the motor.

The motor is supplied from the aircraft net work through the two-pin plug connector.

Current is taken and the generators are supplied with excitation current through the seven-pin plug connector.

The motor-generator is of an enclosed type.

The motor-generator is attached in the horizontal position by the lugs of the support secured on the motor casing.

TECHNICAL DATA

1. Electric motor supply voltage 27 V
2. Current drawn with two generators operating not more than 150 a.
3. Generator load current 15 a
4. Voltage across generator armature terminals... 45 V
5. Current in excitation winding not more than 0.2 a
6. Speed 7500 r.p.m.
7. Weight not more than 30 kg.
8. Operation mode..... 20 min. of operation at rated load and with 2 generators operating simultaneously; 15 minutes of operation at idle running; 20 minutes of operation at rated load and two generators operating simultaneously, after that - complete cooling.
9. Service life 220 hours including 120 hours of operation at rated load and 100 hours at load of up to 10 a.

3. DESIGN

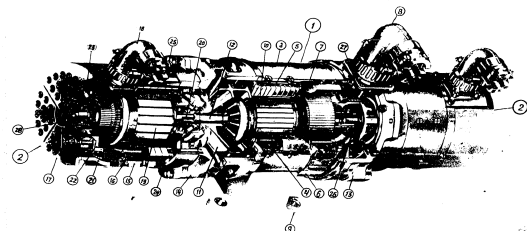


Fig. 2. BA-3H Motor Generator Unit Cut-Away View.

1 - MEA-3 electric motor; 2 - TBA-3H generators; 3 - electric motor casing; 4 - pole; 5 - excitation coil; 6 - protective strip; 7 - brush-holder; 8 - plug connector; 9 - support; 10 - motor armature; 11 - fan; 12 - electric motor shaft; 13, 14 - end housing assemblies; 15 - generator casing; 16 - pole; 17 - hood; 18 - plug connector; 19 - generator armature; 20 - generator shaft; 21, 24 - end housing assemblies; 22 - brush-holder; 25 - bolt; 26, 28 - nuts; 27 - screw.

The MEA-3 electric motor (1) is a 1.c. six-pole motor with the compound excitation winding; the motor consists of the following units: casing, armature, and housing assemblies.

The casing (3) is the magnetic circuit made in the form of a steel tube, screwed to which are six poles (4) with excitation coils (5).

The poles are made of electrotechnical sheet steel; the coils are wound with ПЭ-1 and ПЭП wire.

Secured in the casing is the bracket with six brush-holders(7). The bracket is made of plastic, the brush-holders are cast of brass aluminium alloy.

Installed in the brush-holders are МТС-7 altitude brushes with the gasket made of special alloy; brush dimensions are 7x14 mm., quantity of brushes per one motor is 12.

The brushes are pressed by steel clock springs with a pressure of 420-500 g.

The brush interconnector bars are made of bus-bar copper and placed on the face side of the brush holder bracket ring.

The output leads are connected to the two-pin plug connector(8).

The casing is provided with ports to permit access to the commutator and brushes.

The ports of the casing are covered with the protective strip (6); a small part of the port remains open to provide an additional air supply for cooling the electric motor commutator⁽¹⁾.

Attached to the casing (3) is the support with lugs for attaching the motor-generator unit.

The armature (10) is made of electrotechnical sheet steel and has slots placed in which is the winding made of ПЭП bus-bar copper. The ends of the winding are soldered to the commutator. The frontal parts of the winding are fastened with steel wire bindings. The armature lamination assembly is placed on the aluminium hub provided with axial passages to pass air for cooling the armature(10).

Installed on the shaft (12), at the end opposite to the commutator is the turbine-type fan provided with two rows of blades. The fan is made of magnesium alloy. On both ends of the shaft are holes in which the ends of the TDA-5A generators shafts are placed. The shaft (12) rotates in ball bearings No. 86204 with safety washers. The ball bearings are filled with lubricant at the Mfr's plant.

The end housing assemblies (13 and 14) are made of aluminium alloy and attached to the casing from both sides by the screws. On the housing assembly end are flanges with holes for attaching the generators (2) to the electric motor (1).

Located on the end housing assembly (13) side is the pipe for air supply (see external view of the unit) and two-pin plug connector.

On the end housing assembly (14) side are holes to permit escape of air ejected by the fan.

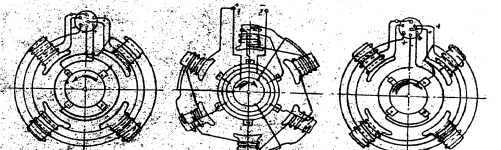


Fig. 3. Schematic Diagram of Motor-Generator Unit

The generators (12) are d.c. four-pole generators with two independent excitation windings and one series winding. The generator with the index "1" is intended for azimuth rotation and the generator with the index "2" - for elevation movement.

The generators (12) consist of the following main units: casing, structure, and winding assembly.

The casing (13) is the magnetic circuit made in the form of a test tube, attached to which are four poles with excitation coils.

Mounted on the casing are the excitation coils with the series winding (14) and (15) and (16) and (17).

Provided in the casing are the openings to permit access to the excitation coils.

The structure (18) is made of steel and is mounted on the casing.

The winding (19) is made of copper wire and is mounted on the structure. The winding is made of 1.5-2 mm wire; its ends are soldered to the commutator.

The shaft (20) rotates in ball bearings mounted on the casing and is connected to the commutator. The shaft has a key mounted on it, filled with lubricant at the key seat.

The armature shaft has the shank for connection to the commutator (1) shaft.

The excitation assemblies (21, 24) are made of magnetic and aluminum alloys and are screwed to the casing from both sides.

Secured to the excitation assembly (21) is the bracket with four brush-holders (22). The bracket is made of plastic, the brush holders are stamped of brass sheet.

- 11 -

Placed in the brush holders (22) are ME-6 altitude brushes. Brush dimensions are 6,5x10,4 mm; quantity per generator - 4 brushes. The brushes are pressed by steel clock springs with a pressure of 400-450 g.

The interconnector bars are made of bus-bar copper and placed in the slots on the face side of the brush-holder bracket ring.

The end housing assembly (24) from the commutator side and openings in the casing (15) are closed by a steel stamped hood (25); on the face side of the hood are holes to permit ram air access. The hood is secured to the casing by screws (27).

The flange end housing assembly (3) is provided with four lugs with holes for attachment of the generator (2) to the 15W-4 electric motor (4).

II. MV-550TY ELECTRIC MOTOR

I. GENERAL

The MV-550TY electric motors are designed to rotate the 15W-4 turret in azimuth and elevation.

The electric motor armature is supplied from the EDA-9A generator of the EA-9A motor-generator.

The MV-550TY electric motor is a 240 v.c. reverse-type, four-pole motor with independent excitation.

The electric motor is provided with the built-in solenoid braking clutch. The clutch can be disengaged manually.



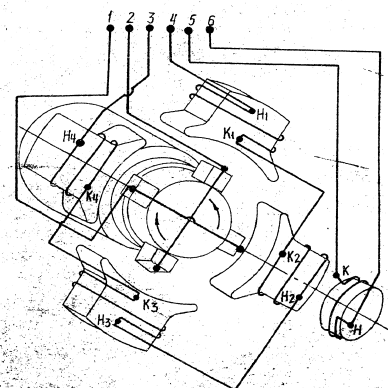
Fig. 4. MV-5501V Electric Motor.

2. TECHNICAL DATA

1. Voltage across armature 50 V
2. Voltage across excitation winding 27 V
3. Current drawn by the armature not more than 17.5 A
4. Speed 6000 r.p.m. $\pm$ 8%
5. Torque on shaft (at the ground) 10 kg-cm.
6. Weight not more than 6.5 kg.
7. Operating mode 20 min. of operation at rated load, followed by 15 min. interval with excitation winding and solenoid clutch winding energized, then 20 min. of operation at nominal load, after that - complete cooling.
8. Service life 75 hours of operation in the following mode: 15 min. of operation at a torque on the shaft of 0.707 of the nominal value, at voltage of 50 V across armature and 27 V across excitation and solenoid clutch windings, followed by 15 min. interval with excitation and solenoid clutch windings energized by 27 V and 9296

armature de-energized. Such a cycle is repeated during the whole service life.

NOTE: The service life does not include idle running (15-min. interval during cycles adjustment and intervals at zero torque on the shaft).



- 14 -

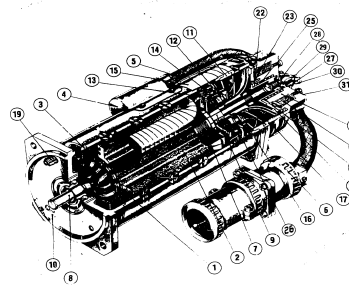


Fig. 6. MY-550TF Electric Motor Cut-Away View

- 1 - Casing; 2 - pole; 3 - excitation coil; 4 - terminal box;
- 5 - screening hose; 6 - plug connector; 7 - armature; 8 - shaft;
- 9 - commutator; 10 - end housing assembly from drive side;
- 11 - end housing assembly from commutator side; 12 - support;
- 13 - brushes; 14 - springs; 15 - protective strip; 16 - flange;
- 17 - fan; 18 - cork ring; 19 - pins; 20 - clutch casing; 21 - clutch
- coil; 22 - locking washers; 23 - guide pins; 24 - brake washer;
- 25 - spring; 26 - adjusting washer; 27 - link; 28 - lug; 29 - axle;
- 30 - cup; 31 - washer-cover.

B. S E L S Y N S

1. GENERAL

The selsyns are a.c. synchronous machines with a single-phase concentrated winding on the rotor and three-phase distributed winding on the stator.

The selsyns are intended for remote synchronous coupling of the KUC-50A sighting set and AL-85M turret.

The sighting set and turret have two independent motions - in azimuth and elevation. Therefore, provided in the turret motion system controlled from the sighting set are two independent channels: azimuth and elevation aiming channels.

The synchronous coupling for each channel of the gun aiming is ensured by four selsyns:

- two KC-3 transmitting selsyns located on the gun aiming station; the selsyn rotors are supplied with 115 V, 400 c.p.s. a.c. from the aircraft system.
- two KC-4 receiving selsyns, located on the turret drive reduction gear, and supplied with voltage up to 55 V from the three-phase secondary windings of the transmitting selsyns.

The receiving selsyns rotors are connected to the input transformer of the amplifier.

Besides the transmitting and receiving selsyns each aiming channel of the system has two differential selsyns located in the computer unit.

The differential selsyns are provided with three-phase distributed windings both on the stator and rotor.

When operating with the computer, the differential selsyn

turns in addition to the transmitting selsyn turning angle by the correction angle set by the computer.

This total signal is supplied to the receiving selsyn.

2. KC-3 TRANSMITTING SELSYN



Fig. 7. KC-3 Transmitting Selsyn.

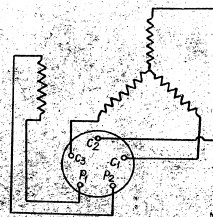


Fig. 8. Schematic Diagram of Transmitting Selsyn.

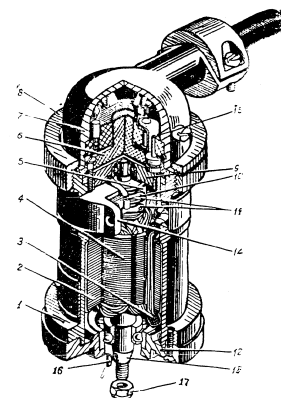


Fig. 9. Transmitting Selsyn Cut-away View

- 1 - Casing; 2 - stator; 3 - stator winding; 4 - rotor; 5 - contact rings; 6 - plug; 7 - socket; 8 - coupling nut; 9 - inner bearing race; 10 - brush-holders; 11 - brushes; 12 - outer bearing race; 13 - rotor shaft; 14 - brush-holder bracket; 15 - plug pins; 16 - segment key.

3. TECHNICAL DATA OF TRANSMITTING SELSYN

1. Rated input voltage 115 V
2. Max. output voltage 55 V
3. Rated input current 0.092 a
4. Frequency 400 c.p.s.
5. Max. angle adjustment error $\pm 1^\circ$
6. Weight 9.3 kg
7. Operating duty continuous

4. KC-4 RECEIVING SELSYN

The KC-4 receiving-selsyn constructionally differs from the KC-3 transmitting selsyn in the shape of the armature; due to that the receiving selsyn has different electrical characteristics and is not interchangeable with the transmitting selsyn.

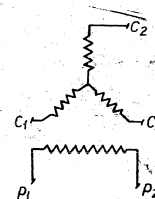


Fig. 10. Schematic Diagram of Receiving Selsyn.

5. TECHNICAL DATA OF RECEIVING SELSYN

1. Rated input voltage 55 V
2. Max. output voltage 55 ± 1 V
3. Rated output current not more than 0.003 A
4. Frequency 400 cps.
5. Max. angle adjustment error $\pm 1^\circ$
6. Weight 0.3 kg.
7. Operating duty continuous.

6. OPERATION OF TRANSMITTING AND RECEIVING SELSYNS

Given in Fig. 11 is the connection diagram of the transmitting and receiving selsyns.



Fig. 11. Transmitting Selsyn-to-Receiving Selsyn Connection.

1 - Sighting set; 2 - transmitting selsyn rotor; 3 - transmitting selsyn stator; 4 - turret; 5 - receiving selsyn rotor; 6 - receiving selsyn stator.

The transmitting selsyn rotor (2) is mechanically connected to the sighting set (1) and outputs in the a.c. network of 115 V, 400 c.p.s.

The stator three-phase winding of the transmitting selsyn is electrically connected to the stator three-phase winding of the receiving selsyn.

The transmitting selsyn is designed to have maximum voltage between two terminals of the stator (3) three-phase winding is 55 V, i.e. transformation ratio is 0.5.

The rotor (5) of the receiving selsyn is mechanically coupled with the turret (4) and the rotor winding is connected to the amplifier input.

When turning the transmitting selsyn rotor (2), voltage across the selsyn stator windings changes according to the sinusoidal law.

The resultant magnetic flux of the transmitting selsyn stator (3) is always parallel to the rotor flux. The stator windings of the transmitting and receiving selsyns are connected to each other, so that a current flowing in the receiving selsyn windings creates magnetic flux which is parallel to the receiving selsyn stator (3) flux and has the same sense. Under the action of magnetic flux of the receiving selsyn stator, voltage is induced in the winding of the transmitting selsyn rotor (5); the value of the voltage depends on the mutual position of the transmitting and receiving selsyn rotors.

The aligned position is the position when the rotors axes are perpendicular to each other and voltage across the receiving selsyn rotor equals to zero.

The receiving selsyn is designed so that max. voltage across rotor winding terminals is 55 V.

Thus, the system incorporating two selsyns (transmitting and receiving) operates as a transformer with rotating windings.

The primary circuit of this transformer is the transmitting selsyn rotor (2) winding, the secondary - the receiving selsyn rotor (5) winding.

The operation principle of the remote gun aiming selsyn system is given in fig. 12 and 13.

The Fig. 12 illustrates that the position of the rotors axes relative to each other at an angle of 90 deg. corresponds to a synchronous position of the sighting set and turret; voltage across the receiving selsyn rotor (5) is zero.

If the sighting set and, hence, the transmitting selsyn rotor (2) are turned at some angle relative to the gun, i.e. to the receiving selsyn rotor (5), electromotive force is induced in the receiving selsyn rotor (see Fig. 13).

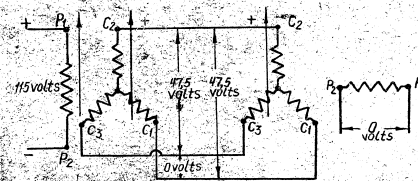


Fig. 12. Sighting Set and gun Aligned Position
(Signal at the receiving selsyn output is zero)

Voltage picked up from the terminals of the receiving selsyn rotor (5) winding is called "signal" as it indicates deflection of the sighting set for gun from the aligned position (misalignment angle).

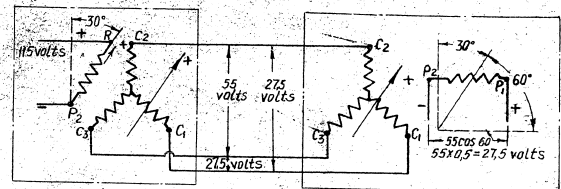


Fig. 13. 30 deg. Misalignment Position of Sighting Set and Turret

(Signal at the receiving selsyn output is proportional to misalignment angle)

1 - transmitting selsyn; 2 - receiving selsyn.

When turning the transmitting selsyn counterclockwise, an output signal of the receiving selsyn depends on the misalignment angle but its instantaneous polarity is opposite to the signal produced when turning the transmitting selsyn rotor clockwise.

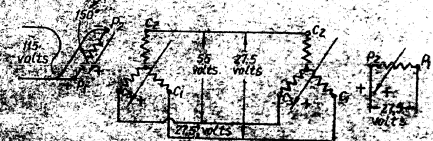


Fig. 14. Position of Transmitting Selsyn Rotor Turning by 150°

In case of a misalignment position of the sighting line and gun axis in azimuth and elevation the electric signal of misalignment appears at the receiving selsyn rotor; this signal amplified in the magnetic amplifier is supplied to the excitation winding of the generator.

The generators, supplying the electric motors, make the turret move in the direction of decreasing the misalignment.

7. DIFFERENTIAL SELSYN PURPOSE AND OPERATION

The differential selsyn is used to produce a signal in addition to the main signal, i.e. to introduce the correction allowing for target relative speed, shell ballistic deviation and parallax.

Provided are two coarse and two fine differential selsyns which are located in the computer unit.

The differential selsyn rotor is turned by means of the computer unit mechanisms to introduce corrections.

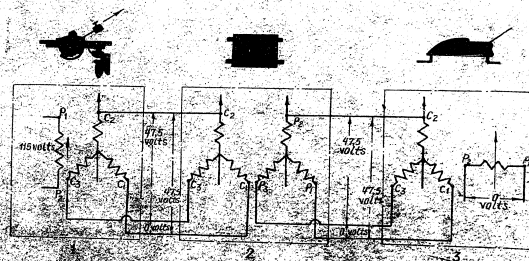


Fig. 15. Connecting of Differential Selsyns to Selsyn

Electric Circuit.

1 - transmitting selsyn; 2 - differential selsyn; 3 - receiving selsyn.

When correcting the synchronous follow-up system, the computing mechanism of the ABC-2571 automatic air-firing unit rotates the differential selsyn rotor.

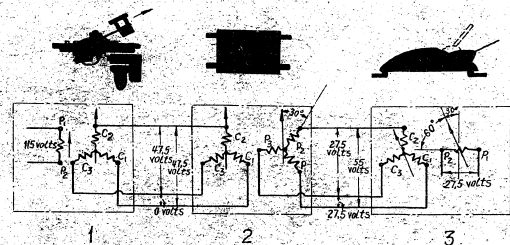


Fig. 16. Influence of Differential Selsyn Rotor Turning counterclockwise by 30° on Value and Polarity of Receiving Selsyn Rotor Voltage.

1 - Transmitting selsyn; 2 - differential selsyn; 3 - receiving selsyn.

When the differential selsyn rotor turns, magnetic flux in the receiving selsyn rotor turns too; due to that a voltage occurs in the receiving selsyn rotor, whose value and direction depends on the differential selsyn turning.

8. COARSE AND FINE SELSYN SYSTEM

Each aiming channel is provided with two transmitting selsyns (coarse and fine) installed in the sighting set and two receiving selsyns (coarse and fine) installed on the turret.

The rotors of the four transmitting selsyns (in both channels) are connected to the sighting set through the reduction gear; when the sighting set turns, the rotors rotate relative to their stators.

The rotors of the coarse transmitting selsyns turn exactly through an angle of the sighting set turning; the rotors of the fine transmitting selsyns turn through an angle 31 times more.

The rotors of the four receiving selsyns (in both channels) are connected to the reduction gears of the turret drives. The coarse receiving selsyn rotors turn through an angle of the gun turning, the rotors of the fine receiving selsyns turn through an angle 31 times more.

The coarse and fine selsyns ensure synchronous movement of the sighting set and guns in the same direction.

Due to the fact that the selsyns have considerable constructional errors at comparatively ^{low} angles of misalignment the coarse selsyns only cannot ensure the required accuracy of system synchronization.

Since fine selsyns rotors rotation speed is 31 times more than that of the sighting set and turret, the fine selsyn rotor turning at 1° produces an actual error between the sighting line and bore axis 31 times less than 1° , i.e. $1:31 = 1:97$.

Using of the fine selsyns only cannot ensure a proper functioning of the system. Actually, the fine transmitting and receiving selsyns rotors can occupy 31 synchronous positions for 1 revolution of the sighting set.

Besides, if the sighting set is turned at an angle exceeding $180^{\circ}31'50''49''$ the changed polarity of the signal voltage causes a rotation of the gun in the direction of the nearest synchronous position of the rotors, i.e. causes an increase in misalignment of the gun and sighting set. Thus, using of the coarse and fine selsyns in the system is necessary but the spheres of their applications are strictly delimited.

The coarse selsyns control the gun movement at the misalignment angle exceeding $2.5^{\circ}-4.5^{\circ}$, when the fine selsyn rotors misalignment is less than 180° .

C. AMPLIFIER, AMPLIFIER UNIT

1. ELECTRONIC-MAGNETIC AMPLIFIER, Model V-2M-IM

1. GENERAL

The V-2M-IM amplifier is designed:

- a) to magnify and convert input signals supplied from the selsyn system into direct current signals required to control the d.c. generators of the BA-3A motor-generator;
- b) to reverse the drive with the change in instantaneous polarity of control signal;
- c) to change automatically the driving channels from the coarse to the fine control and vice versa.

2. TECHNICAL DATA

1. A.C. voltage 220 V
2. A.C. frequency 50 Hz

3. Output initial direct current
in each arm with zero input signal 80-170 m.A.
4. Difference of output currents
at max. input signal and load resistance
of 224 ohms not less than 300 mA.
5. Max. output power of one channel... not less than 20 W.
6. A.C. input signal voltage 0-55 V
7. Input signal frequency..... 400 c.p.s.
8. Amplifier power drawn at
max. input signal not more than 370 va
9. Weight 13.5 kg.

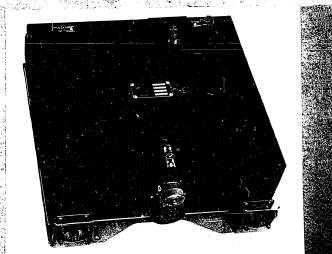


Fig.17. Y-2M-IM Amplifier

3. DESIGN

The Y-2M-IM electronic magnetic amplifier is simple in construction: it is a duralumin plate incorporating all components of the circuit described below.

To prevent the circuit components from mechanical damage, the amplifier is closed with a cover; glued to the inside of the cover is the diagram.

The amplifier is connected to the cable system through the plug connector.

The amplifier is installed on shock-mounts in the brackets of the base which is provided with holes for attaching the amplifier in aircraft.

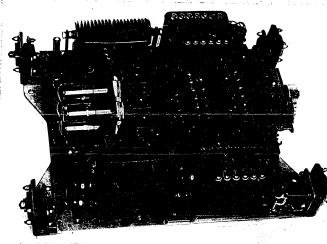


Fig.18. Schematic Diagram of V-2M-1M Amplifier.
(Without cover)

Listed in table No.1 are the components incorporated in the V-2M-1M amplifier and their designation. Given in the first column are designations of the components according to the wiring diagram and in the second column - according to the schematic diagram.

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Table No.1

LIST OF COMPONENT PARTS INCORPORATED IN J-22-1M AMPLIFIER
AND THEIR NAMES

Designation according to Wiring Diagram	Designation according to Schematic Diagram	Model	Number	Name
R1, R2	R1, R2		2	Germanium rectifier units
Tr1	Tr1 (1-2P) Tr2 (1-2P)		2	Input transformer of channel Wilson
R3	R3, R3a, R5, R5a	BC-0.5-1-0.54 -11-510 Kohms	4	Composition resistor
	R4, R4a, R6, R6a	BC-0.5-1-0.1- -11-100 Kohms	4	Limiting of valve anode current.
	Tr3 (T-9A) Tr7 (T-9A)		2	Interstage transformer
C1, C1a	C1, C1a	PC-5-500-1 -1500-1	2	Electrolytic cap- sitor of channel channel valve anode circuit.
RG-2	RL (RT-2)	PH-2	1	Cut-in relay of valve amplifier anode circuits.
R9, R9a, R10, R10a	R9a, R9, R10, R10a	BC-0.5-0.1-11	4	Composition resistor, 100000 ohms 0.5W, absorbent fine self-sys. voltage.
R11, R11a	R11, R11a	BC-0.5-1-510-11	2	Carbon resistor, 510 ohms, 0.5 W

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1	2	3	4	5
				Automatic bias in valves cathode circuit.
R12, R12 ¹	R12, R12 ¹	PC-25H3-1200 ohms	2	Adjustable resistor of automatic bias in valves cathode circuit.
C3, C3 ¹ , C4, C4 ¹	C1, C3a, C4, C4a	MBIT-2-400-0-11-A	4	Smoothing capacitor at amplifier output.
C3a, C3 ¹ , C4a, C4 ¹	C5, C5a, C6, C6a	MBIT-2-400-1-11-A	4	
R15, R16	R15, R16		2	Adjustable bias resistor of second (upper) valve.
R13, R13 ¹ , R18, R18 ¹	R14, R14 ¹ , R13, R13a	MSB-2-400-0-11	4	Non-adjustable resistor. Thermal compensation of magnetic amplifier positive feedback winding.
AP1(I, RMV ¹ -I)	AP1(RM ¹ -I)		2	Differential magnetic amplifier.
T10A	AP2(RMV-I)			
T1, T1 ¹	TP4(T-10A)		1	Power transformer
	TP1(T-1), TP5(T-1)		2	Input transformer of fine signal
R19, R19 ¹ , R20, R20 ¹	R19, R19a, R20, R20a			Adjustable resistor in magnetic amplifier bias circuit.
		R _{max} = 1100 ohms 10 W	4	

1	2	3	4	5
C2, C2 ¹	C2, C2 ²	WV-MI-3E-1000-3- -0.05-II	2	Smoothing capacitor of magnetic ampli- fiers control windings.
HL, HL ¹ , HL ² , HL ³	HL-1, HL-2, HL-3, HL-4	6H8C	4	Amplifying valves of coarse and fine aiming channels.
HL ³ , HL ⁴ , HL ⁵ , HL ⁶	HL-1, HL-2, HL-3, HL-4	MI-V		Neon tube of control change-over from coarse to fine channels.
R17, R17 ¹ , R17, R18 ¹	R17, R17 ¹ , R18, R18 ¹		4	Adjustable resistor to adjust amplifi- cating factor.
PI		PP46HCHT2	1	Plug connector of amplifier-to-other units connection.
PE		BP-7	1	Test plug connector.

4. PRINCIPLE OF OPERATION

Provided in the T-2M-1M amplifier are two similar channels: one to control the gun aiming in azimuth (the components are mounted on the left side of the panel - as viewed from the plug connector), the other - to control gun aiming in elevation (the components are located on the right side of the panel).

Both channels (elevation and azimuth) have the common transformer to supply valves anode circuits, cathodes filament circuits, automatic bias and power magnetic amplifier.

Each channel comprises two stages:

1) Electronic stage of preliminary amplification, based on electron valves model 6H8C connected in the differential circuit, is a phase-detecting element of the amplifier; due to that reversing of the system is accomplished.

2) Power output stage based on two magnetic amplifiers also connected in the differential circuit; the magnetic amplifiers are loaded by the generators excitation windings connected in opposition.

The preliminary (electronic) stage of amplification has two control channels: one channel - for the fine signal, the other - for the coarse one.

Used in both channels are the double triodes model 6H8C.

The channels are provided with independent inputs for control signals and supplied from various sources (see Fig. 48a, Amplifier Schematic Diagram).

a) Fine Channel of Gun Aiming

The gun aiming fine channel consists of the T-1 input transformer, four BC protective composition resistors of 100000 ohms (R4, R6, R9, R10).



in the valve grid circuits, one 6H8C valve of duo triode-type, one composition resistor (R11) of 510 ohms for automatic bias in the valve cathode circuit and balancing bridge.

The balancing bridge consists of the R15 potentiometer and T-10A transformer secondary winding which has a middle point.

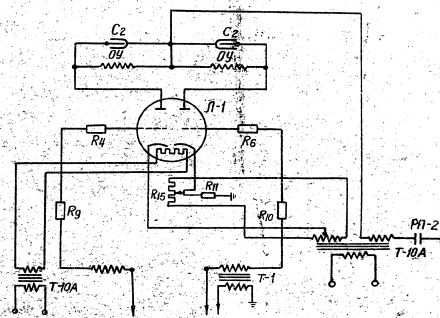


Fig. 13. Fine channel of gun aiming.

The balancing bridge is designed to equalize anode currents in both triodes at zero control signals on their grids.

When moving the R15 potentiometer wiper relative to its middle position, negative bias of one of the triodes changes, due to that anode currents are balanced in case of different anode characteristics of the triodes depending on constructional parameters and total electron tolerances.

899c

The anode circuit of the valve is loaded with control windings of the magnetic amplifiers.

The anode valve is supplied from the T-10A power transformer with 200 V a.c., 400 c.p.s.

When misalignment angle occurs, a signal is sent to the primary of the T-1 input transformer from the fine selsyn rotor; electromotive force induced in each of the transformer secondaries is two times less than that of the primary.

The secondary windings are connected in series through the R13, R9, R10, R14 resistors incorporated in the V-2M-15M amplifier circuit: the middle point between the R9 and R10 resistances is connected to "minus".

The secondary windings electromotive forces are supplied through the protective resistors R9, R4 and R10, R6 to the VI valve control grids and change their bias. If voltage instantaneous polarities at anodes and one of the control grids are positive, the anode current in this triode increases. In this case the anode current in the second triode decreases as the potential on its grid is negative (See Fig.19).

With the change in the anode instantaneous polarity, control grid polarity also changes but current does not flow through the anode circuit as the anodes will have negative potential.

Thus, increase in current takes place in one triode during positive half-period.

The anode control currents difference is intensified by the magnetic amplifiers and creates magnetic flux in the generator; due to that a voltage appears on the generator armature.

The electric motor connected to the generator terminals will rotate decreasing the misalignment angle.

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With the sighting set movement changed in the opposite direction the input signal changes its instantaneous polarity, i.e. voltage phase is 180° shifted.

The anode polarity alternation remains the same. In this case the anode current increases in the second triode and decreases in the first. The generator voltage changes its polarity and the electric motor rotates in the opposite direction also decreasing the misalignment angle.

b) Course Channel of Gun Aiming

The gun aiming coarse channel consists of the TWA input transformer with transformation ratio 1:6; two protective resistors R3 and R5 in the valve grids circuit, one R12 adjustable resistor for automatic bias, 6H8C valve, one interstage transformer model T-9A with transformation ratio 1:4 and two neon tubes model NB-7 serving as the voltage electronic switch.

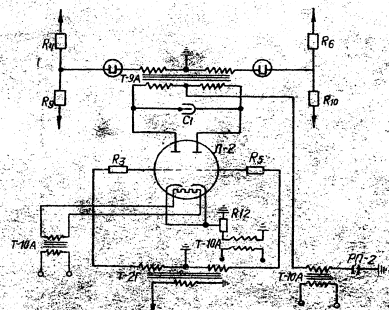


Fig. 20. Coarse Channel of Gun Aiming.

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The input circuit and valve operate as in the fine channel.

Voltage is supplied to the T-3L transformer primary from the coarse selsyn rotor.

The T-9A transformer primaries serve as the anode load. As the current flows through the anode circuit for one half-period, a ripple current will flow through the transformer primary winding; this current induces in the T-9A transformer secondary windings an electromotive force with the frequency of the control signal.

When the electromotive force in the secondary windings reaches the value equal to ignition potential of neon tubes the latter supply this voltage to the control grids of the III fine channel valve and the system control is automatically switched over to the coarse channel. If the electromotive force in the T-9A transformer secondary windings reduces to extinction potential of neon tubes the latter go out and switch over the system control to the fine channel.

When supplying input signal voltage of 1.7-2.7 V to the T-2T transformer primary from the coarse selsyn rotor the coarse channel is switched on and off.

Voltage supplied from the T-9A transformer secondary windings to the fine channel control grids has an amplitude of 2-3 times of maximum voltage supplied from the T-1 transformer of the fine channel.

At misalignment angles of up to $5^{\circ}49'$ the phases of these voltages have the same sign.

If the misalignment angles exceed the above value the fine channel signal phase changes its sign every $5^{\circ}49'$, but the grids move in the same direction since a positive heightened potential of constant phase sign is supplied to the II valve grid from the coarse channel.

Due to this that only one synchronous point is obtained in the system synchronous circuit as the second synchronous point is unstable.

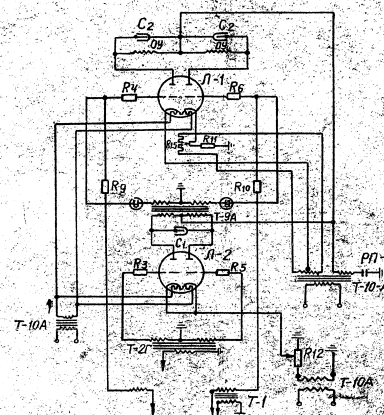


Fig. 21. Electronic Part of Amplifier.

c) Magnetic Power Amplifier

The magnetic power amplifier is based on the principle of changing inductance of a coil with an iron core depending on simultaneous magnetizing with direct and alternating currents.

Any coil located on a closed circuit iron core has the coefficient of self-inductance depending on the squared number of turns of coil, core geometrical dimensions and its physical properties, i.e. the ability to be magnetized. These physical properties are called magnetic inductivity.

If the alternating current flows through the coil, the current

value is directly proportional to voltage across the coil and inversely proportional to inductive reactance in the saturated portion of the characteristics for magnetic induction.

The inductive reactance is proportional to a.c. frequency and inductance.

Hence, with the change of magnetic inductivity of iron, and consequently of inductance, the current flowing through the coil changes too.

In case of simultaneous magnetizing of the iron core by d.c. and a.c. the magnetic inductivity, and hence the inductance, change sharply.

These properties of the coil with the closed-circuit iron core are used in the magnetic power amplifier, i.e. by changing the iron core magnetizing with d.c. component, a control is made of a.c. flowing in power windings of the magnetic amplifier.

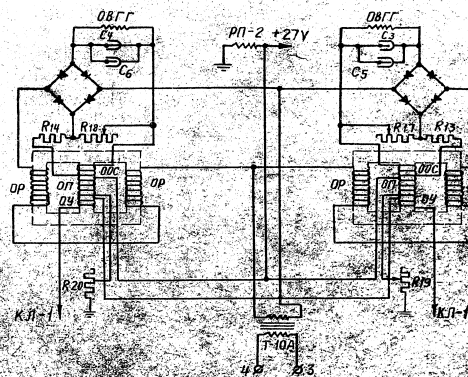


Fig. 22. Differential Magnetic Amplifier Diagram.

Each aiming channel consists of two magnetic power amplifiers connected in differential circuit.

The magnetic amplifiers are assembled on a Π -shaped laminated mo-permalloy core and are completely identical.

The extreme rods of the core are wound with a.c. windings (OF) connected in series. Wound on the middle rod are:

- a) positive feedback winding (OOC), which serves to increase the power gain;
- b) bias winding (OH) supplied with 27 V d.c. from the aircraft electrical system. Connected in series with this winding is the adjustable resistor (R19) intended to adjust initial output current and to compensate for initial currents of the triodes connected in series with the control winding. The bias winding ampere-turns are opposite to the feedback and control windings ampere-turns;
- c) control winding (OY) supplied with output current from the amplifier electronic stage. The C2 capacitor is connected in parallel to the control winding to smooth current ripples.

Since the generator control windings are fed with d.c., the selenium rectifier assembled according to a bridge full-wave circuit is connected in series with a.c. winding at the magnetic amplifier output.

The current flowing through the a.c. windings is rectified and passes the generator control winding.

Connected in series to the generator winding is the positive feedback winding (See Fig. 22).

Connected in parallel to the positive feedback windings is the adjustable resistor R17 to adjust the amplification factor.

As the amplifier operates within a wide range of ambient and temperature ranging, temperature compensation consists of the

resistor is used for stabilizing the amplification factor; the R13 resistor is connected in series with the positive feedback winding. Connected in parallel to the amplifier output are capacitors C₁, C₂, C₄, C₆ used as smoothing filters.

To prevent mechanical damages of the magnetic amplifiers cores, the latter are placed in the diamagnetic casing - one for two amplifiers.

Thus with a misalignment appearing, a voltage supplied to the amplifier input through the T-1 transformer changes the currents flowing through the MI valve ampere circuit; due to that currents flowing through the magnetic amplifiers control winding change too.

In the magnetic amplifier where the current in the control windings increases (in accordance with the output signal polarity) the iron core magnetic inductivity decreases which causes decrease in inductive reactance of the coils energized with alternating current.

With decrease in inductive reactance the current flowing through these coils increases which causes increase in the rectified current passing through the generator control winding connected in series with the magnetic amplifier a.c. coils.

This rectified current passing through the magnetic amplifier positive feedback winding changes inductive reactance still more which results in further increase in current.

Thanks to the positive feedback the increase in current should not exceed the value stipulated by the parameters of the positive feedback.

If the magnetic amplifier where the current flows through the control winding decreases, the alternating current decreases too (due to the increase in the inductive reactance).

Due to that there would be a decrease in the direct current flowing through the generator control winding connected to the given magnetic amplifier.

In the generator control winding a current difference occurs which in its turn magnetizes the generator. On the generator armature there would be a voltage whose value is proportional to the difference of these currents or misalignment angle.

The drive electric motor connected to the generator armature is energized and starts rotating in the direction of decrease in the misalignment angle.

II. V-2M-10M AUXILIARY AMPLIFIER UNIT

I. GENERAL

Dynamic errors of the system greatly depend on the parameters of the drive electric motor, i.e. from its time constant which in its turn depends on the moment of inertia and resistance of the armature, on connecting wires resistance and generator characteristics.

The time constant of any electric motor is the value of time required for the motor to attain 63% of the speed final value (since the moment of supplying to the electric motor of constant, by value, voltage).

To ensure stable operation of the system (without self-oscillations) negative feedback circuits should be provided; the value of the time constant of these circuits should exceed that of the drive electric motor.

Negative feedback with a considerable value of the time constant causes large errors in the misalignment angle when the turret moves with acceleration.

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To decrease the misalignment angle error it is necessary to increase the gain for the control signal from the seleya system or decrease the gain for the negative feedback; thus results in instable operation of the system, i.e. in self-oscillations.

Therefore, to decrease error and ensure stable operation, the Y-2M-12M auxiliary amplifier unit for the control signal is connected in the system circuit; this amplifier unit increases the gain of the main Y-2M-12M amplifier depending on the input signal: the more the input signal, the more the gain, which changes nonlinearly up to a definite value.

At small misalignment angles of up to 4 angular minutes the auxiliary amplifier unit does not send signals and the system does not change the gain.

Thanks to the variable gain the system operation is accurate and stable at all modes.

2. TECHNICAL DATA

1. A.C. voltage - 115 volt
2. Frequency - 400 c.p.s.
3. Power consumption - 20 va
4. Weight - 2.5 kg.

3. DESIGN

The Y-2M-12M auxiliary amplifier unit consists of two input transformers T_1 and T_2 , one - for azimuth and the other - for elevation aiming channel.

The primary windings of these transformers are connected in parallel to the corresponding primary of the input transformers of the fine channels of the V-2M-1M amplifier. Their secondary windings are connected through the protective resistors R5, R6 and R7 to the control grids of two duotriodes Model 6H6C (4_1 and 4_2).

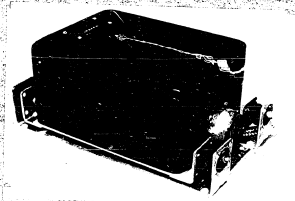


Fig. 23. V-2M-1M Auxiliary Amplifier Unit.

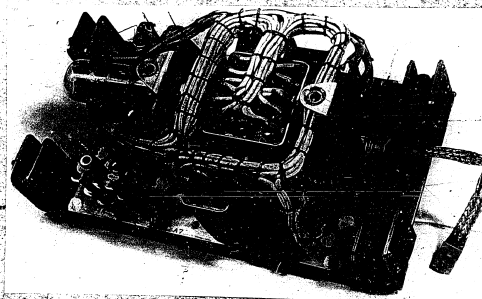


Fig. 24. V-2M-1M Amplifier.

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Connected to the circuit of each cathode of Π_1 and Π_2 valves are potentiometers R1, R2 and R3 and R4 which are supplied from the secondary windings of the T-5 power transformer common for both channels.

These potentiometers serve to supply to the control grids the forced negative bias.

Connected in series to this potentiometer are resistors R9 and R10 (for Π_1) and R11 and R12 (for Π_2 valve); the middle point of the resistors is grounded.

These resistors serve as a load in the cathode circuit of the triodes.

Connected in parallel to the resistors R9, R10, R11 and R12 are the capacitors C3, C4, C5, C6 which are used as ripple filters.

Connected to the potentiometers R1, R2, R3, R4 - to resistors R9, R10, R11, R12 joints are the resistors R13, R14, R15, R16 and the other ends of the T₁ and T₂ input transformers secondary windings.

The resistors R13, R14, R15, R16 are those of the negative feedback circuit.

All the components of the auxiliary unit are installed on a shock-absorbing duralumin panel.

To prevent mechanical damages to components the latter are closed with a housing. The Y-2M-1M amplifier unit is connected to the Y-2M-1M amplifier through the outer circuit by means of a plug connector.

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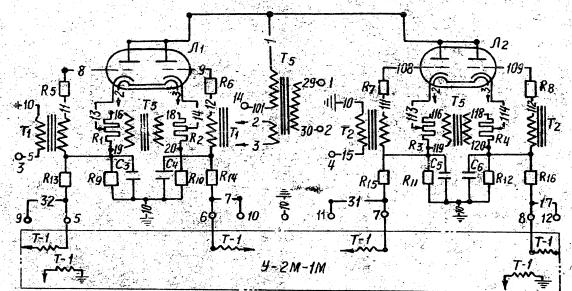


Fig.25. Schematic Diagram of Y-2M-1M Amplifier Unit.

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Table No.2

LIST

OF COMPONENT PARTS INCORPORATED IN Y-2M-1EM AMPLIFIER UNIT AND THEIR NAMES

Designations according to diagram wiring	Designations according to schematic diagram	Model	Number	Name
1	2	3	4	5
R9,R10	R9,R10	REC-0.5 W 10 Kohms	2	Composition resistor; load of triodes connected to cathode (azimuth channel).
C3,C4	C3,C4	MMT-3-160 0.5-H-F	2	Metal-paper capacitors, ripple filters.
T1	T1		1	Input transformer of fine channel to aim in azimuth.
R1,R2	R1,R2	R _{max} 68 ohms	2	Variable wirewound resistors for adjusting azimuth channel valve bias.
			1	Power transformer to supply anode and filament circuits.
		6H6C	2	Amplifying valves.

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2	3	4	5	
R13	"BC"-0.5W			Stabilizing circuit.
R14	75 Kohms	2		resistor of azimuth feedback.
R15	"BC"-0.5W	2		Stabilizing circuit
R16	75 Kohms			resistors of elevation feedback.
R5	"BC"-0.5W			Resistor limiting
R6	0.1 meg.	2		grid current of azimuth channel
R7	"BC"-0.5W			valve.
R8	0.1 meg	2		Resistor limiting grid current of elevation channel valve.
R11, R12	R11, R12 BC-0.5W 10 Kohms	2		Composition resistor; load of triodes connected to cathode (elevation channel).
C5, C6	C5, C6 M50-8-100 0.5-H-B			Metal-paper capacitors, ripple filters.
T2	T2	1		Input transformer of fine channel to aim in elevation.
R3, R4	R3, R4 R _{max} = 68 ohms	2		Variably wirewound resistor for adjusting elevation channel valve bias.
K1				Negative terminal
PI	IPG2114H15	1		Plug connector of auxiliary amplifier unit to other units connection.

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4. PRINCIPLE OF OPERATION

The principle of the V-2M-11M auxiliary unit operation is similar to that of the V-2M-11M amplifier and differs from the latter in the fact that at zero input signal the Π_1 and Π_2 valves are cut-off, i.e. supplied to the control grids is such a negative bias that current does not flow through the anode circuit.

With the control signal exceeding 1.5-2 V one of the Π_1 valve triodes (due to instantaneous polarity) sharply increases its anode current which passes the R9 and R10 resistors (the second channel is identical) and causes a voltage drop proportional to anode current; the polarity of this voltage is always the same and "plus" is at the point connected to the R13 and R14 resistors.

This positive voltage is supplied through the R13 and R14 resistors to the input transformer windings and is an additional signal to the main one.

At this time the other triode of the Π_1 valve is cut off and does not send an additional signal.

With the change in polarity of the control signal the triodes operation changes:

This alternating signal ensures the required accuracy of the output signal.

D. FIRE SYSTEM UNITS

I. A3-1AM FIRE INTERRUPTER

1. GENERAL

The A3-1AM fire interrupter is designed for automatic interrupting of fire at large misalignment angles between the line of sight and line of aim to prevent hitting the friendly aircraft flying in the formation.



Fig.26. A3-1AM Fire Interrupter

2. TECHNICAL DATA

1. A.C. voltage..... 115 V
2. A.C. frequency..... 400 cps
3. Max. voltage of control signal..... 50 V
4. Current drawn by control signal at voltage of 50 V..... not more than 10 mA

5. Max. power consumed by
interrupter 15 Va
6. Weight not more than 2.2 kg.
7. Operation mode - two cycles following each other without
interval. Each cycle consists of 15-min.
operation at zero input signal and 15-min.
operation at max. input signal.

3. DESIGN

The fire interrupter consists of the following main components: magnetic amplifier, power and input transformers, relay, selenium rectified units, adjustable resistors and capacitors which are attached to the bottom directly or through the intermediate posts.

Provided in the bottom are holes for attaching the fire interrupter to the aircraft.

To prevent the fire interrupter from dust, dirt, mechanical damages and weather conditions, it is covered with the housing.

The interrupter is provided with the plug connector for connecting to the general circuit.

The list of components incorporated in the fire interrupter, their main data and purpose are given in table 3.

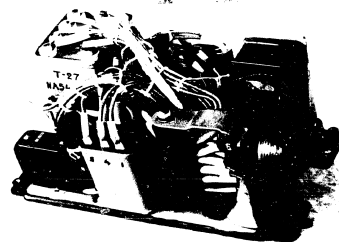


FIG. 27. AB-1AM Fire Interrupter (without housing)

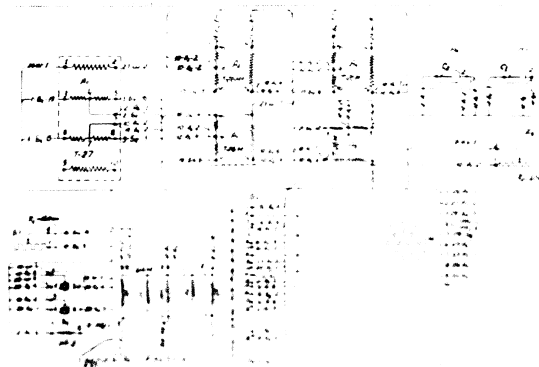


FIG. 28. Fire Interrupter Wiring Diagram

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Table No. 3

L I S T

OF COMPONENT PARTS INCORPORATED IN FIRE INTERRUPTER MODEL A3-1AM
AND THEIR NAMES

Designation according to wiring diagram	Designation according to schematic diagram	Model	Number	Name
1	2	3	4	5
A1	T27	T-27	1	Power transformer
A2	T-26M1	T-26M1	1	Input transformer of azimuth coarse channel.
A4	T-26M1	T-26M1-1	1	Input transformer of elevation coarse channel.
A3	T-26M	T-26M	1	Input transformer of azimuth fine channel.
A5	T-26M	T-26M	1	Input transformer of elevation fine channel.
A6	C2	500P-8 ICO-4-II-B	1	Smoothing capacitor in relay winding circuit.
A7	C1	Do	1	Smoothing capacitor in magnetic amplifier con- trol circuit.
A8	R2	Rmax. 9.2 ohm	1	Adjustable resistor in magnetic amplifier feed- back circuit.
A9	HO-10	A9 ohms	1	Temperature compensation in amplifier feedback circuit.

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1	2	3	4	5
51	R1	R _{max.} = 160 ohms	1	Adjustable resistor in magnetic amplifier bias circuit.
52	PH-2	PH-2	1	Relay de-energizing fire control circuit.
53	V-4M	V-4M	1	Magnetic amplifier
54	-	-	1	Selenium rectifying pile
55	-	HP02N10HMT	1	Plug connector of fire interrupter-to-other units connection

4. PRINCIPLE OF OPERATION

The fire interrupter for protecting from non-aimed firing is a magnetic amplifier; connected to its output is the PH-2 relay control winding. The normally-closed contacts of this relay are connected into the fire control circuit.

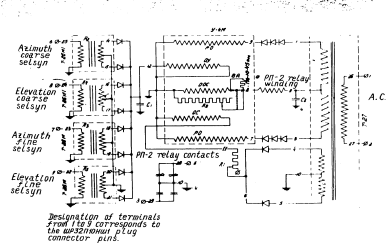


Fig. 29. Schematic Diagram of AJ-1AM Fire Interrupter.

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The magnetic amplifier is controlled from the selsyn system through the input transformers by the azimuth and elevation aiming channels, both the fine and coarse ones.

The voltage of the A_2 , A_4 , A_3 , A_5 input transformers secondary windings are rectified by selenium rectifiers and supplied in parallel to the magnetic amplifier common control winding.

Thus, with the misalignment angle of a definite amount for azimuth or elevation channels, the current at the amplifier output increases up to the value of the PH-2 relay actuation; when the relay is actuated it disconnects the fire control circuit by means of its normally-closed contacts.

With decrease in the misalignment angle the output current of the amplifier drops and the relay is de-energized thus closing the fire control circuit. Hence, with the misalignment angles dangerous for the friendly aircraft, the firing is automatically ceased.

The magnetic amplifiers operation is described in the section "V-2M-1M Amplifier".

The fire interrupter automatically disconnects the fire control circuit if the misalignment angles exceed 0.5° to 3° .

2. AUTOMATIC RECHARGER Model AH-27

The AH-27 automatic recharger is designed for automatic (without the gunner) recharging the AM-23 gun in case of the gun stoppages which can be eliminated by recharging.

Each gun is provided with the automatic recharger.

The automatic recharger consists of the relays installed on a magnesium cast base and protected with a housing from mechanical damages and weather conditions.

939c

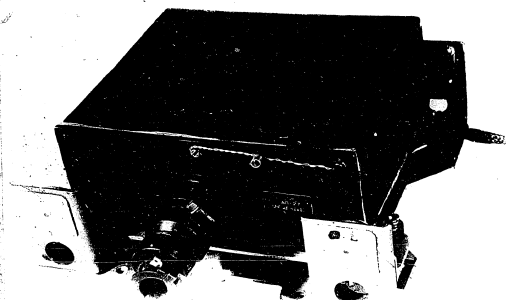


Fig.30. AL-27 Automatic Repcharger

TECHNICAL DATA

1. Rated supply voltage..... 27 V d.c.
2. Current drawn not more than 1.2 a
3. Operation mode continuous
4. Delay time from the moment
stopping the turret moving
parts on the front transmitter
till energizing the electropneu-
matic valve, secured by the PB-1 and
PB-2 relays at a temperature of $+20^{\circ}\pm 5^{\circ}\text{C}$ 0.4-0.6 sec.
5. Delay time of PBC relay at at
temperature of $+20^{\circ}\pm 5^{\circ}\text{C}$ 0.1-0.2 sec.

6. Time of the electro-pneumatic valve being energized by the FN-3 relay at a temperature of $-20^{\circ} \pm 5^{\circ}\text{C}$ when eliminating stoppages: "the turret moving parts are short of the extreme front position" 0.18-0.35 sec.
7. Automatic recharger weight not more than 3.8 kg.

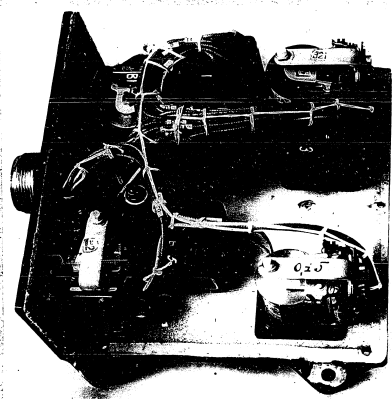


Fig. 34. Automatic recharger (without cover and shock absorber)

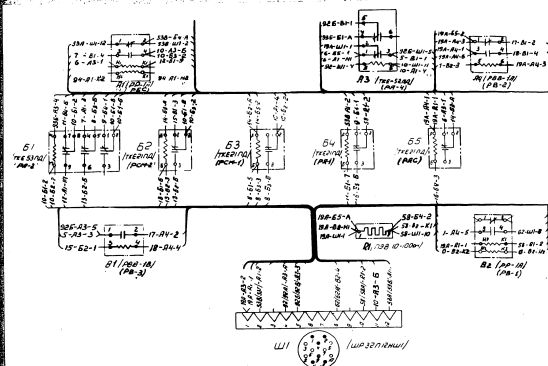


Fig. 32. Cording Diagram.

Table No. 4

LIST

OF COMPONENT PARTS INCORPORATED IN AN-27 AUTOMATIC RECHARGER
AND THEIR PURPOSE

Designation according to cording diagram	Designation according to schematic diagram	Number	Name and Purpose
2	3	4	5
M4	PR-2	1	PRD-1A time relay with time delay for release of 0.3 sec ±10% to control pneumatic recharging.

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2	3	4	5
BP	PP-1	1	PP-1A time relay with time delay for release of 0.05 sec. with winding connected in parallel and 0.1 sec. with one winding shorted (middle winding is shorted) to control the PB-2 relay closing.
ES	PAC	1	TR-311M quick-acting relay for automatic drop of pneumatic chargings count when resuming firing.
AD	PA-4	1	TR-321M quick-acting relay for manual recharging.
SI	PA-2	1	TR-331M quick-acting relay to control electrical circuits in case of pneumatic chargings.
A4	PP-2	1	PP-1A time relay with time delay for release of 0.05 sec. with windings connected in parallel, and 0.1 sec. with one winding shorted (middle winding is shorted) to interlock solenoid.
ES	PCM-1	1	TR-341M counting relay for counting the first pneumatic charging (at the end of pneumatic charging).
P2	PCM-2	1	TR-351M counting relay for counting the second subsequent pneumatic charging (operates at the beginning of the second pneumatic charging and cuts off supply of PB-3 time relay).

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1	2	3	4	5
B1	PA-3	1	PBA-1a time relay with time delay for release of 0.5 sec. $\pm 10\%$ to control pneumatic charging.	
B4	PA-1	1	TRK211M quick-acting relay controls additional supply of PA-1 relay.	
-	R1	1	100-10-100 ohms resistor to increase time delay for release of PA-1 relay.	
B1	-	1	BTCH211M plug connector of recharger-to-other units connection.	

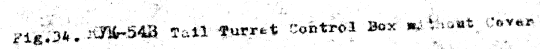
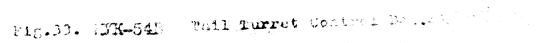
E. CONTROL AND CHECK EQUIPMENT

Incorporated in the AB-65V turret remote-control system is the following control and check equipment.

1. KKK-54B Tail Control Box
2. PH-4M Turret Main Control Panel
3. PH-5aM Turret Auxiliary Control Panel
4. KKK-4 Ammunition Booster Boxes for Right and Left Gun.

I. KKK-54B Tail Turret Control Box

The KKK-54B tail turret control box is designed for automatic change over the units incorporated in the AB-65V turret remote-control system.



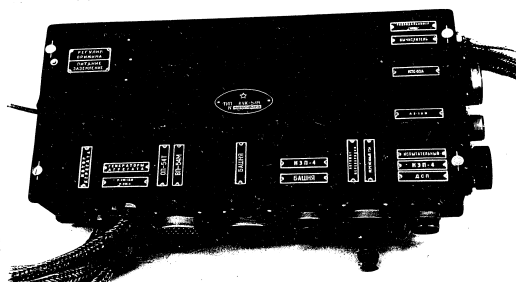


Fig. 33. NVK-54B Tail Turret Control Box with cover

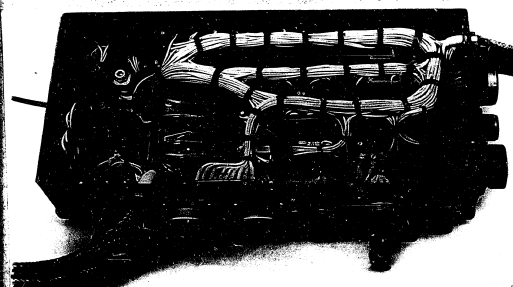


Fig. 34. NVK-54B Tail Turret Control Box without cover

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Table No. 2

LIST

COMPONENT PARTS INCORPORATED IN KLV-448 CONTROL UNIT AND THEIR

NAME

Position going to gram	Designation according to schematic dia- gram	Model	Number	Name
1	2	3	4	5
1	PM-1, PM-2	PM-3	1	Out-in relay of ammunition counters electric motors of left and right guns during recharging (manual or automatic).
2	PCM	PM-2	1	Out-in relay of computer warning light.
7, 18	CD, C6	CD-ME-108 CD-ME-1-11	2	Capacitors in receiving solenoid rotors circuit.
9	R1	Adjust. resist. R _{max} = 1,100 ohms	1	Adjustable resistor for setting gun to extreme position in azimuth.
10	R2	Adjust. resist. R _{max} = 1,100 ohms	1	Adjustable resistor for setting gun to extreme position in elevation.
51	T3	ACC-5	1	Thermostat of turret lighting and left and right guns discharging circuits.

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	2	3	4	5
32	PHI-2	PH-C	2	Cut-in relay of generators control windings of elevation channel.
33	PHI-1			channel.
34	PHI-2	PH-C	2	Computer cut-in relay.
35	PHI-1			
36	PHI	PH-C	1	Target tracking relay.
37	PHI-2	PH-C	2	Cut-in relay of generators control windings of azimuth channel.
38	PHI-1			
39	CI	MSM-2-600-0.5-II	2	Stabilizing circuit capacitors of azimuth channel.
40	CI	MSM-2-600-0.5-II	1	
41	PMI	PM3	1	Cut-in relay of camera gun and acquisition boosters.
42	PV-1	PH-2	2	Control relay.
43	PV-2			
44	PMI-3	PH-2	1	Cut-in relay of PMI-1 and PMI-2 relays control windings.
45	PMI-1	PH-2	1	Cut-in relay of PAI-1 relay control winding.
46	PMI-2	PH-2	1	Cut-in relay of PMI-3 relay control winding.
47	PHI-1	PH-2	1	Relay of gun stowed position in azimuth.
48	PHI-1	PH-2	1	
49	PHI-1	PH-2	1	Relay of gun stowed position in azimuth.
50	PHI-2	PH-3	1	
51	CI	MSM-2-600-0.5-II	1	Stabilizing circuit capacitors of elevation channel.
52	CI	MSM-2-600-0.5-II	1	

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2	3	4	5
K-2	KM-200A	1	Contactors to energize electric motor of motor-generator unit.
PI	PI-230A	1	Relay for supplying P-3 unit
PI	PI-230B	1	Relay interlocking control circuits in the absence of 115 V.
PIB	PI-3	1	Relay for supplying computing unit with a.c.
PIA-2	PI-2	2	Relay for disconnecting electromagnetic clutches and excitation windings of drive electric motors.
PIA-1			
PI-2	PI-1A	2	Switching relay of drive motors
PI-1	PI-1A		dynamic braking contactors.
PI-2	PI-50A	2	Drive electric motors dynamic braking switching contactors.
PI-1	PI-50A		
CS	NET-MI-3B-600-2x0.1-H	2	Earthing capacitors
PII	PII	1	A.C. switching relay
PII	PI-20B	1	Fire contactor
PII	PI-25A	1	Switching relay for supplying "Gamma" range finder radar with a.c.
PII	PI-2		
PII	NET-MI-2-600-0.25-H	2	Spark-quenching capacitors in contactors normally-closed circuits of PIA-1 and PIA-2 relays.
			Negative bus-bar.
			Positive terminal.

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2	3	4	5	
EPF60M47H02	(plug)	1	Plug connector for KVA-54B control box-to-ABC air fire control unit connection.	
EPF40H0763M2	(receptacle)	1	Plug connector for KVA-54B control box-to-"Gamma" range finder radar junction box connection.	
EPF40H0763M2	(receptacle)	1	Plug connector for KVA-54B control box-to-"Gamma" range finder radar unit No.3 connection.	
EPF50H0763M2	(receptacle)	1	Plug connector for KVA-54B control box-to- "CIC-53A" sighting set connection.	
EPF20H0763M2	(receptacle)	1	Plug connector for KVA-54B control box-to-AB-14B fire interrupter connection.	
EPF40H0763M2	(receptacle)	1	Test plug connector	
EPF20H0763M2	(receptacle)	1	Plug connector for 115 V. A.C. supply.	
EPF20H0763M2	(receptacle)	1	Plug connector for KVA-54B control box-to- "E3H-4" left gun ammunition booster box connection.	
EPF20H0763M2	(receptacle)	1	Plug connector for KVA-54B control box-to-air speed and density unit connection.	

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	2	3	4	5
9	MP48H28HT2 (receptacle)	1	plug connector for KVA-54B control box-to-AB-27 left and right guns automatic rechargers connection.	
10	MP62H10HT1 (receptacle)	1	Plug connector for KVA-54B control box-to-AB-4 right gun ammunition boosters connection.	
11	MP62H12HT1 (receptacle)	1	Plug connector for KVA-54B control control box-to-AB-55 turret connection.	
12	MP60H47HT2 (receptacle)	1	Plug connector for KVA-54B control box-to-AB-55 turret connection.	
13	MP60H45HHT (plug)	1	Plug connector for KVA-54B control box-to-control panels connection: KVA-54B main control panel and BL-54B auxiliary control panel.	
14	MP48H28HT2 (plug)	1	Plug connector for KVA-54B control box-to-7-2M-1M amplifier connection.	
15	MP62H14HT5 (plug)	1	Plug connector for KVA-54B 7-2M-1M auxiliary amplifier unit.	
16	MP40H14HT2 (receptacle)	1	Plug connector for KVA-54B control box-to-PSA-30 generator of SA-30 motor-generator connection.	
18	MP48H28HT2 (receptacle)	1	Plug connector for KVA-54B control box-to-AMA-3 electric motor of A-20 motor-generator connection.	

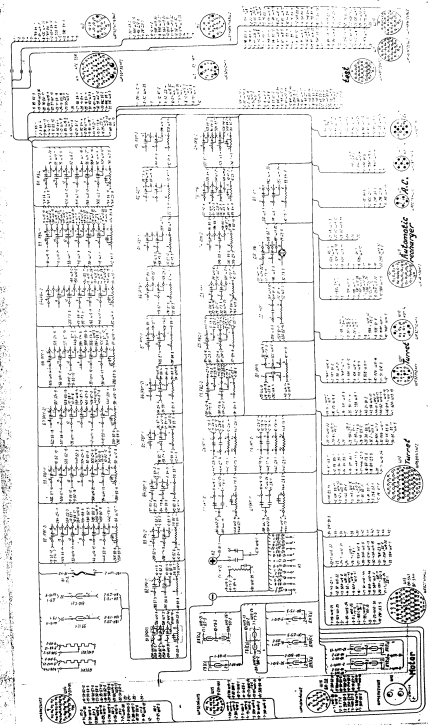


Fig. 35. KW-54B Control Box Wiring Diagram.

II. OH-54T TAIL TURRET MAIN CONTROL PANEL

A. GENERAL

The OH-54T main control panel is intended for automatic control fire and to control the "Gamma" range finder radar operation.

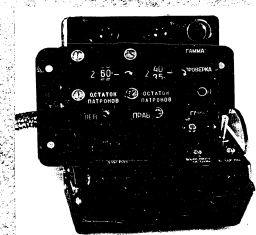


Fig. 36. OH-54T Main Control Panel

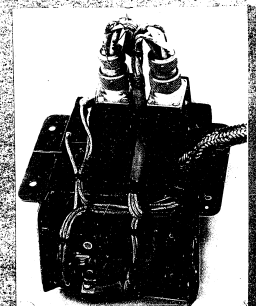


Fig. 37. OH-54T Main Control Panel (rear view)

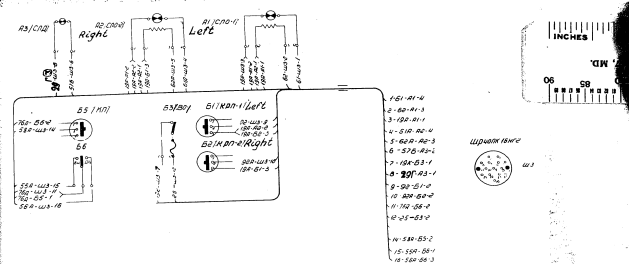


Fig. 3B. OL-54T Main Control Panel Cording Diagram

Table No. 6

LIST

OF COMPONENT PARTS INCORPORATED IN OL-54T MAIN CONTROL PANEL AND
THEIR NAME

Designation according to cording diagram	Designation according to schematic diagram	Model Number	Number	Name
1	COH-1	YCL-1	2	Ammunition Reserve counter of left and right guns.
2	COH-2			
3	CUT	MT-51	1	Warning light of "Gamma" range finder radar operation.
4		MT-5	1	
5	KPL-1	204K	2	Left and right guns manual recharging buttons.
6	KPL-2			
7	BO	430-10	1	Right and left guns fire control switch.
8		204K	1	"Gamma" range finder radar operation check button.

2	3	4	5
AM	HM-45	1	"Gamma" range finder radar nearest and distant target switch.
EPACORRICHIEZ (plug)		1	Plug connector for connection with control box and aux. control panel.

III. BU-54M TURRET AUXILIARY CONTROL PANEL

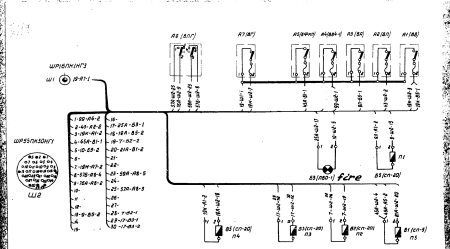
I. GENERAL

The BU-54M auxiliary control panel is intended for energizing the turret automatic control circuits.



Fig. 29. BU-54M Auxiliary Control Panel

Fig. 40. BU-54M Auxiliary Control Panel (rear view)



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Table No. 7

1 1 3 2

OF COMPONENTS PARTS INCORPORATED IN THE-54M AUXILIARY CONTROL
PANEL AND THEIR NAME

Designation according to wiring dia- gram.	Designation according to schematic diagram	Model	Number	Name
1	2	3	4	5
A1	BB	ADC-20	1	Auxiliary circuits switch.
A2	BI	ADC-5	1	A.C. switch
A3	BA	ADC-15	1	Motor-generator switch
A4	BSN-I	ADC-15	1	Air fire control unit computer switch
A5	BSM	ADC-5	1	Camera gun switch
A7	BT	ADC-10	1	"Gamma" range finder radar switch.
A8	BT	2HH-45	1	Switch of "Gamma" range finder radar pulse generator.
B5	BO-I	CSH-51, CH-XX (red)	1	Left and right guns solenoid's warning light.
B2, B3, B5	B2, B3, B4	CH-20	2	Fuse in auxiliary and generator circuits switch wiring.
B1	B5	CH-5	1	Fuse in camera gun switch circuit.

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1	2	3	4	5
1	III	CH-80	1	Fuse in motor-generator switch circuit.
		CH-5	1	Spare fuses
		CH-20	4	
2		MP55HKSCHT (receptacle)	1	Plug connector for connection with KVK-54 control box and CH-54 main panel.

IV. KOL-4 AMMUNITION BOOSTER BOX

1. GENERAL

The KOL-4 ammunition booster box is designed for automatic and manual switching of two electric motors of cartridge belt.

The box components are mounted on the base and closed with the cover to prevent mechanical damages.

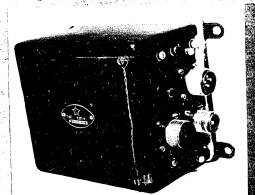


Fig. 42. KOL-4 Ammunition Booster Box

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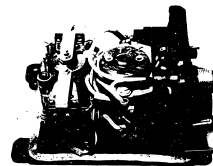


Fig. 43. K3H-4 Ammunition Booster Box (without cover)

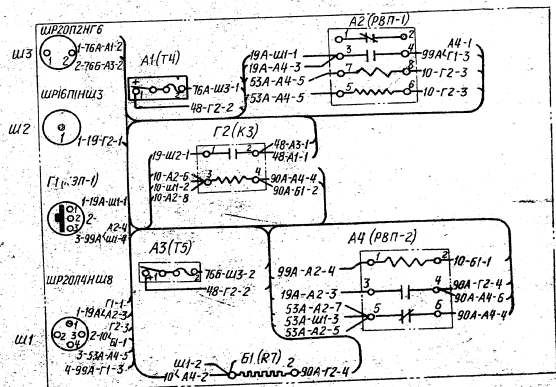


Fig. 44. K3H-4 Ammunition Booster Cording Diagram

Table No. 8

LIST

OF COMPONENT PARTS INCORPORATED IN RSH-4 AMMUNITION BOOSTER BOX
AND THEIR NAMES.

Designation according to wiring diagram	Designation according to schematic diagram	Model	Number	Name
A1	24	A30-40	1	Circuit breaker in ammunition booster electric motors armature circuits.
A2	25	A30-40	1	Time intermediate relay with time delay for release of 40-70 milliseconds; serves to switch on ammunition booster electric motors.
A3	26	PTB-1A	1	Time relay with time delay for release of 0.3-0.4 sec.; serves for switching ammunition booster contactor.
BT	27	204K	1	ammunition booster manual switching button.
BT	28	KN-50A	1	ammunition booster switching contactor.
BT	29	RSH-10-100 ohms	1	Non-adjustable wire-wound resistor connected in parallel to ammunition booster contactor winding to increase time for release.
BT	30	RP2041HES	1	Plug connector for RSH-4 ammunition booster box-to-remote control circuit connection.

	2	3	4	2
12		HP1811H1E3	1	Plug connector for KSM-4 ammunition booster box-to aircraft electric system connection.
13		HP20H2H1E6	1	Plug connector for KSM-4 ammunition booster box-to booster motor connection.

NOTE: The HB-237 gun armament system is provided with two KSM-4 ammunition booster boxes. One of them switches two motors to boost the left gun cartridge belt, the other - two motors to boost the right gun cartridge belt. Each KSM-4 ammunition booster box operates independently. The KSM-4 ammunition booster boxes are similar in construction and operation. They are interchangeable.

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SECTION II

ELECTRICAL CONTROL SYSTEMS

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SECTION II

ELECTRICAL CONTROL SYSTEM

Given in Section I of this technical description are purpose, principle of operation and design of the definite electrical units incorporated in the HP-65V turret remote-control system of the AH-12 aircraft.

Given in Section II is the description of the definite electrical systems sequence and mutual operation of the elements incorporated in the HP-65V turret system.

The HP-65V gun armament schematic diagram is given in Fig. 45a.

14)	Transmitting selsyn		10)	Normally-closed contacts of relay, contactor, armament transmitter.
12)	Receiving selsyn			
13)	Differential selsyn		11)	Switch
14)	Electric motor		12)	Changeover switch
15)	Electric generator			
16)	Adjustable resistor		13)	Circuit breaker
17)	Relay, electromagnet, solenoid, clutch winding, shunt or independent field winding of electrical machine.		14)	Thermoswitch
18)	Series winding of electrical machine		15)	Button
19)	Contacting winding		16)	Limit switch
20)	Normally-open contacts of relay, contactor, armament transmitter.		17)	Interlocking contact of limit switch
			18)	Transformer
			19)	Constant capacitor
			20)	Ohmic resistor
			21)	Warning light
			22)	Solid rectifier element
			23)	Fuse
			24)	Ground (aircraft structure)

Fig. 45. Table of Designations to Schematic Diagrams.

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SECTION II ELECTRICAL CONTROL SYSTEM

Given in Section I of this technical description are purpose, principle of operation and design of the definite electrical units incorporated in the HP-65V turret remote-control system of the AM-12 aircraft.

Given in Section II is the description of the definite electrical systems sequence and mutual operation of the elements incorporated in the HP-65V turret system.

The HP-65V gun armament schematic diagram is given in Fig. 45a.

1) Transmitting selsyn		10) Normally-closed contacts of relay, contactor, armament transmitter.
2) Receiving selsyn		
3) Differential selsyn		11) Switch
4) Electric motor		12) Changeover switch
5) Electric generator		
6) Adjustable resistor		13) Circuit breaker
7) Relay, electromagnet, solenoid, clutch winding, shunt or independent field winding of electrical machine.		14) Thermoswitch
8) Button		15) Limit switch
9) Series winding of electrical machine		16) Interlocking contact of limit switch
10) Contactor winding		17) Transformer
11) Normally-open contacts of relay, contactor, armament transmitter.		18) Constant capacitor
		19) Ohmic resistor
		20) Warning light
		21) Solid rectifier element
		22) Fuse
		23) Ground (aircraft structure)

Fig. 45. Table of Designations to Schematic Diagrams.

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KEY to FIG. 45a.

Sub- tion	No.	Design- ation	Name	Number	Model	Place of installa- tion	Remarks
1	2	3	4	5	6	7	8
Computer and Sighting Set	1	HC	Sighting set	1	KHC-53A	Pressurized cabin	
	2	ABC	Air firing unit	1	ABC-257- -1	Outside of pressurized cabin	BB-257I
	3	ACH	Air speed and density transmitter	1	ACH-257- -1	Pressurized cabin	BB-257-I
	4	ATS	Charge tem- perature transmitter	1	ATS-157	Outside of pressurized cabin	BB-257-I
	5	GMH	Camera gun	1	GMH-457-2	KHC-53A	
	6		"Gamma" range finder radar	1		Outside of pressurized cabin	
	7	KB	Collimator sight	1	K-53	KHC-53A	
	8	FP-F FP-B	Azimuth and elevation rate gyro	2	FP-3	KHC-53A	
Electric Units	9.	CMP-I	Coarse trans- mitting sel- syn, azimuth	1	KC-3	KHC-53A	
	10.	CMP-3I	Fine trans- mitting sel- syn, azimuth	1	KC-3	KHC-53A	
	11	CMB-I	Coarse trans- mitting sel- syn, eleva- tion	1	KC-3	KHC-53A	
	12	CMB-3I	Fine trans- mitting sel- syn, eleva- tion	1	KC-3	KHC-53A	
	13	CMP-I	Coarse re- ceiving sel- syn, azimuth	1	KC-4	AB-657	
	14	CMP-3I	Fine receiv- ing sel-syn, azimuth	1	KC-4	AB-657	

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1	2	3	4	5	6	7	8
15	CHP-I	Coarse receiving selsyn, elevation	1	KC-4	AB-C5Y		
16	CHP-SI	Fine receiving selsyn, elevation	1	KC-4	AB-C5Y		
17	ASA	Motor-generator unit electric motor	1	MEA-BA	BA-BA		
18	OMAA	ASA motor-gene- rator unit field winding	2				
19	AI	Azimuth drive Generator	1	EPA-BA	BA-BA		
20	OBIT	Azimuth drive generator field winding	3				
21	EB	Elevation drive generator	1	ELA-BA	BA-BA		
22	OBEB	Elevation drive generator field winding	3				
23	AI	Azimuth drive motor	1	AV-550TV	AI-55Y		
24	OBIT	Azimuth drive motor field winding	1				
25	AE	Elevation drive motor	1	AV-550TV	AE-55Y		
26	OBEB	Elevation drive motor field winding	1				
27	OBEB	Elevation drive motor field winding	1				
28	OB3H-3	3H-3 ammunition booster field winding	1			Cartridge box AB-5Y	
29	3H-2 3H-1	Electric motor of cartridge belt ammunition booster(left gun)	1	AK-7			
30	OB3H-1	3H-1 ammunition booster field winding	1			Ammunition box AE-55Y	
31	3H-4 3H-3	Electric motor of cartridge belt ammunition booster(right gun)	1	AK-7			
32	OB3H-2	3H-2 ammunition booster field winding	1				
33	OB3H-4	3H-4 ammunition booster field winding	1				

1	2	3	4	5	6	7	8
34	K-2	Motor-generator unit contactor	1	KM-200A	K/K-54B		
35							
36	K-3	Contactors in ammunition booster electric circuit.	1	KM-30A	KCH-4	left	
37	K-4	Contactors in ammunition booster electric circuit	1	KM-50A	KCH-4	right	
38	K-1	Time delay relay in ammunition booster circuit	1	PT-1A	KCH-4	left	
39	PBM-3	Time delay relay in ammunition booster circuit	1	PB-1A	KCH-4	right	
40	PCH-1	Cut-in relay of left and right ammunition boosters	2	PB-3	KCH-4		
41	PCH-1	Cut-in relay of elevation generator	2	PH-3	KCH-4		
42	PCH-1	Cut-in relay of azimuth generator	2	PH-3	KCH-4		
43	PCH-1	Stowed position relay, elevation	1	PH-3	KCH-4		
44	PCH-1	Stowed position relay, azimuth	1	PH-3	KCH-4		
45	PCH-1	A.S. cut-in relay	1	PH-2	KCH-4		
46	PBM-1	Cut-off relay of PCH-1 and PCH-2 relays with the gun set in stowed position in elev. and azimuth	1	PH-2	KCH-4		
47	PBM-2	Cut-in relay of PCH-1 and PCH-2 relays	1	PH-2	KCH-4		
48	PBM-3	Cut-in relay of PCH-1 and PCH-2 relays	1	PH-2	KCH-4		

1	2	3	4	5	6	7	8
49	PE-1	Cut-off relay of solenoid clutch and azimuth motor field winding	1	PE-2	KT-54A		
50	PE-2	Cut-off relay of solenoid clutch and elev. motor field winding	1	PE-3	KT-54B		
51	PY-1 PY-2	Control relay	2	PE-4	KT-54C		
52	PGT	Fire control contactor	1	EA-25	KT-54D		
53	PGI	Cut-in relay of gun and ammunition booster	1	PE-5	KT-54E		
54	PT-1	Dynamic braking relay of elev. motor	1	PT-1A	KT-54F		
55	PT-2	Dynamic braking relay of azimuth motor	1	PT-1A	KT-54G		
56	KT-1	Dynamic braking contactor of elev. motor	1	KT-50A	KT-54H		
57	KT-2	Dynamic braking contactor of azimuth motor	1	KT-50B	KT-54I		
58	PE	Interlocking relay	1	CTB-221A	KT-54J		
59	HTB	Computer a.c. cut-in relay	1	PI-3	KT-54K		
60	HTT	A.C. cut-in relay of "Gamma" range finder radar	1	PI-2	KT-54L		
61	P8L	Target locking relay	1	PE-6	KT-54M		
62	PCW	Computer warning light cut-in relay	1	PI-2	KT-54N		
63				PI-2	KT-54O		
64	PB4-1 PB4-2	Computer cut-in relay	2				
65	P8O	Fire cut-off relay at high misalignment angles	1	PI-2	AD-1AM		
66	PB4-1 PB4-2 PB4-3	Time delay relay in left gun recharging circuits	1	PI-1A; PIB-1A	AD-27		
939c							

1	2	3	4	5	6	7	8
67	PB-4 PB-5 PB-6	Time delay relay in right gun recharging circuits	1 1 1	1T-1A1 PBB-1A	AI-27		
68	PA-1 PA-2	Separating relay in left gun recharging circuit	1 1	PA-2A1 PBB-1A	AI-27		
69	PH	IP-3 power supply cut-in relay	1	PA-2A1 PBB-1A	AI-27		
70	PA-5 PA-6	Cut-off relay in right gun re- charging circuit	1 1	PA-2A1 PBB-1A	AI-27		
71							
72							
73							
74	PBC-1 PBC-2	Time delay relay per- mitting to eliminate residual compression in left and right guns after recharging	1 1	PA-1A PA-1A	AI-27		
75							
76							
77	PA-3 PA-4	Manual recharging relay of right and left guns	2	PA-2A1 PBB-1A	AI-27		
78	PCM-1 PCM-2 PCM-3 PCM-4	Right and left guns counting relays	4	PA-2A1 PBB-1A	AI-27		
79	PAC-1 PAC-2	Relay of right and left guns recharging countings drop	2	PA-2A1 PBB-1A	AI-27		
80							
81	BA	Motor-generator unit circuit breaker switch	1	AJC-15	AI-27		
82		A.C. circuit breaker switch	1	AJC-5	AI-27		
83	BB	Aux. circuits circuit breaker switch	1	AJC-20	AI-27		
84	BB-1	Camera gun circuit breaker switch	1	AJC-5	AI-27		
85	BB-2	Direct attack switch	1	B-45	AI-27		
86	BB-3	Computer circuit breaker switch	1	AJC-15	AI-27		

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1	2	3	4	5	6	7	8
87	BB4-2	Computer switch	1				KBC-400
88	KC	"Gamma" range finder radar circuit breaker switch	1	438-10			W-54
89	BMP	Oscillator power supply switch of "Gamma" range finder radar	1	ENH-45		W-54M	Aircraft wall
90	EB1-452	Interlocking switches of BA-39 motor-generator	2	B-45			
91	BO	Fire control circuit breaker switch of left and right guns	1	438-10		W-54	
92	KV	Turret control button	1	KB-5-2		W-54M	
93	KC	Fire control button	1	KB-5-2		W-54M	
94	BN	Nearest and distant target switch	1	BN-45		ON-54T	
95	BN						
96	KH	Check button of "Gamma" range finder radar switching	1	204-K		ON-54T	
97	K3H-I K3H-2	Ammunition booster manual switching button	2	204-K		K3H-4 left K3H-1 right	
98	KPH-I KPH-2	Left and right guns manual recharging buttons	2	204-K		ON-54T	
99	KB-B	Upper extreme position limit switch	1	KB-9		AB-65V	
100	KB-H	Lower extreme position limit switch	1	KB-9		AB-65V	
101	KB-I	Left extreme position limit switch	1	KB-9		AB-65V	
102	KB-II	Right extreme position limit switch	1	KB-9		AB-65V	
103	KBI-B KBI-H	Stowed position limit switch in elevation	2	KB-9		AB-65V	
104	KBI-H KBI-I	Stowed position limit switch in azimuth	1	KB-9		AB-65V	
105	K3H-I K3H-2	Ammunition boosters manual switching buttons	2	204-K		Aircraft wall	

939a

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1	2	3	4	5	6	7	8
106	KOLV	Interphone button	1		NO		
107	BC-1	Control panels thermoswitch	1	I _{op} =100A	Aircraft tail switch panel		
			1	I _{op} =70A			
108	BC-2	Thermoswitch in motor-generator circuit	1	I _{op} =130A	Aircraft tail switch panel		
109							
110		Thermoswitch in ammunition boosters circuits	1	I _{op} =120A	Aircraft tail switch panel		
111	T-3	Aux. circuits thermoswitch	1	30-5			
112	T-4	ammunition boosters motor thermoswitch	2	30-40	left		
113	T-6 T-7	ammunition boosters motor thermoswitch	1	30-40	right		
116	R ₁	Resistor of setting in azimuth	1	1000 ohm adjust	CK-714		
117	R ₂	Resistor of setting in elevation	1	1000 ohm adjust	CK-715		
118	R ₃	Resistor for time increasing for release	1	1000-10-100 ohm	left		
119	R ₄	Resistor for time increasing for R-4 release	1	1000-10-100 ohm	right		
120	R ₁₂	Resistor for increasing of time delay of RB-1 and RB-4 relays	1	1000-10-100 ohm	left		
121							
122							
123	C ₁	azimuth channel feedback capacitor	1	MEIL-H-20-10-1-11	548		
124	C ₂	elevation channel feedback capacitor	1	MEIL-H-20-10-1-11	548		
125	C ₃ , C ₄	grounding capacitors in stabilizing circuit.	2	MEIL-H-20-10-1-11	548		
939c							

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1	2	3	4	5	6	7	8
126	C ₅ ;C ₆	Capacitors in receiving selsyn rotors circuit.	2				
127	C ₇	Spark-quenching cap- acitor in relay normally-open contacts circuit.	1				
128	C ₈	Spark-quenching cap- acitor in relay normally-open contacts circuit.	1				
131	H-1	Fuse in motor-generator circuit.	1				
132	H-2	Fuse in azimuth generator circuit.	1				
133	H-3	Fuse in elev. generator circuit.	1				
134	H-4	Fuse in aux. circuits circuit breaker system.	1				
135	H-5	Fuse in camera gun circuit breaker system.	1				
136							
137							
138							
139	CHC-1	Left gun "Ready" warning light	1	CH-31	CHC-31A	Red	
140	CHC-2	Right gun "Ready" warning light	1	CH-31	CHC-31A	Red	
142	CHC-3	Computer operation warning light	1	CH-31	CHC-31A	White	
143	CHC-4	"Gamma" range finder radar warning light	1	CH-31	CHC-31A	Orange	
144	CHC-5	Target locking warning light	1	CH-31	CHC-31A	Green	
145	CHC-6	Fire zone warning light	1	CH-31	CHC-31A	Red	
146	CHC-7	Right and left gun "Fire on" warning light	1	CH-31	CHC-31A	Red	
147	CHC-8						
148							
149							
150							
151							

1	2	3	4	5	6	7	8
151							
152	V-2M-1N		Electronic-magnetic amplifier	1	V-2M-1N	Trans. cabin	10
153	V-2M-1SN		Aux. amplifier unit	1	V-2M-1SN		10
154	A3-1AN		Fire interrupter	1	A3-1AN		10
155	3SM-1		Solenoid clutch of azimuth drive motor	1		3SM-1	10
156	3SM-2		Solenoid clutch of elev. drive motor	1		3SM-2	10
157	COH-1		Left gun ammunition reserve counter	1	COH-1	COH-1	10
158	COH-2		Right gun ammunition reserve counter	1	COH-2	COH-2	10
159	AOH-1		Left gun "Ready" transmitter	1		AOH-1	10
160	AOH-2		Right gun "Ready" transmitter	1		AOH-2	10
161	AOH-1		Left gun rear transmitter	1		AOH-1	10
162	AOH-2		Right gun rear transmitter	1		AOH-2	10
163	AOH-1		Left gun front transmitter	1		AOH-1	10
164	AOH-2		Right gun front transmitter	1		AOH-2	10
165							
166	3C-1		Left gun trigger solenoid	1		3C-1	10
167	3C-2		Right gun trigger solenoid	1		3C-2	10
168	3K-1		Left gun electro-pneumatic valve	1	3K-1	3K-1	10
169	3K-2		Right gun electro-pneumatic valve	1	3K-2	3K-2	10

A. TURRET REMOTE CONTROL

The turret power drive consists of the MY-550W d.c. electric motor with independent excitation; the motor is the actuator of the turret remote control system.

The electric motor armature is directly connected to the armature of the JFA-2A generator which is the rotary power amplifier controlled by the magnetic amplifier.

The magnetic amplifier is in turn controlled from the relay system whose operation is described above.

The relays on the sighting set and turret are installed so that when they are in the aligned position the line of sight coincides with the axis of the bores.

Connected to the generators field windings circuit are normally-open contactors of the generator control relays (PIT-1 and PIT-2 relays - in azimuth and PRT-1 and PRT-2 relays - in elevation), whose control windings are supplied through the limit switches: KB-1 switch - for PIT-1 relay, KB-2 switch - for PIT-2 relays, which restrict the turret motion in azimuth, KB-3 switch - for PRT-1 relay, KB-4 switch - for PRT-2 relay which restrict the turret motion in elevation.

Connected to the generator control relay circuit are also normally-open contactors of PY-1 and PY-2 control relays which are energized from the control button located on the sighting station.

Thus, if the gunner presses the control button with the units energized and turns the sighting set, a misalignment signal appears; the signal is amplified in the amplifier and then in the generator makes the electric motor and thus the turret rotate in the direction

of decreasing the misalignment angle, i.e. in the direction in which the sighting aid is turned. If the gunner rotates the sighting aid within the permissible range of the turret movement, the turret follows the sight with a small misalignment necessary to create the required drive power.

The values of the misalignment angles with the turret moving 20 deg/sec. should not exceed by max. value of 0-10 min. of arc.

The AS-25V turret should ensure the following firing angles:

in azimuth - to the left $70^{\circ}-2^{\circ}$

to the right $70^{\circ}-2^{\circ}$

in elevation - up $60^{\circ}-2^{\circ}$

down $40^{\circ}-2^{\circ}$

relative to the aircraft center line.

Provided in the turret design are mechanical rigid stops for restricting the turret movement.

To prevent the electric drive from burning, when the turret approaches the rigid stops, extreme position limit switches are provided in the remote control system.

When approaching any of the extreme positions one of the limit switches, corresponding to this position, is actuated. The switches off the generator control relay, the winding of which is in series with this limit switch.

The generator control winding is de-energized and voltage produced by the generator drops to minimum.

The electric motor armature is de-energized and the turret stops. When the sight moves in the opposite direction a sign of the control signal from the selsyn system changes and the amplifier supplies voltage to the other control winding of the generator which at this time is still energized. The turret moves from the limit

switched, the turret is closed and the turret is controlled as before. With the turret approaching the extreme position at the max. speed of 10-20 deg./sec. and in case of considerable inertia masses (electric motor armature reduction gears, turret) strong impact is possible which may cause damage to the reduction gear mesh stops, since the limit switches de-energize the electric motor armature within very small range of angles (1.52°) from the rigid stop.

To ensure smooth approaching of the turret to the rigid stop a dynamic braking is provided in the control system. With the limit switch off the electric motor armature is automatically disconnected from the generator and is short-circuited to 10-70 ohms. After that the electric motor armature is automatically reconnected to the generator. With the turret in the extreme position a max. aerodynamic moment acts on the gun barrels and moves the turret from the limit switch.

In this case a misalignment angle appears between the bore axis and line of sight as the sighting set remains in the previous position. Due to that the signal occurs which permits the drive to move the turret to the limit switch thus creating turret oscillations at the limit switches. To eliminate this phenomenon the control system is provided with the electric clutch which presses the guns to the rigid stop.

The control system also provides automatic setting of the turret in the stowed position with the barrels in the line of flight.

If the gunner releases the control button with the sighting set and turret in any position, the latter moves to the stowed position and is locked by the braking solenoid clutch and the elevation and azimuth electric motors armatures are disconnected from the generator and short-circuited.

When pressing the control button the turret is automatically unlocked, the armatures are connected to the generators and the gun is set in the aligned position.

B. STABILIZATION SYSTEM OPERATION

The 220-250V synchronous - follow up system is characterized by high sensitivity relative to the input signal.

With the misalignment angle of 1 min. of arc. the turret starts moving as the drive electric motor armature possesses a considerable inertia, the system is unstable if a special erecting device is not available, i.e. the system starts self-oscillating with the amplitude depending on the drive motor moment of inertia and load characteristics of the generator supplying the given electric motor.

To ensure high sensitivity and stable operation of the system the remote control system is provided with the negative feedback or stabilization circuit, which consists of the capacitor and resistor connected in series and as a whole connected in parallel to the electric motor armature.

The stabilization system operates only when voltage on the drive electric motor armature changes, i.e. in case of transient conditions in the system.

As it is known, the reactance due to capacitance depends on the speed of voltage changing on the capacitor plates. In case of instantaneous supply of constant voltage pulse, the capacitor resistance is infinitely small at the first moment and increases to infinity after some period of time.

If d.c. voltage is instantly supplied to the capacitor circuit connected in series to the resistor, the capacitor is charged and

current will also increase the circuit. At the first moment the value of current is very high and all the voltage supplied to the given circuit appears across the resistor.

After some period of time since the moment of supplying voltage to the circuit, current drops to zero. Voltage which appears across the resistor decreases too; the capacitor plates will have the full voltage.

Time, during which voltage across the resistor equals to 1% of the voltage supplied to the circuit, is called the time constant for the given value and is the product of the capacity value multiplied by the resistor value (capacitance is measured in microfarads, resistance in mega and time - in sec.).

To ensure steady operation of the remote control system the time constant of the stabilization system should exceed that of the drive electric motor.

Voltage which appears across the stabilization system resistors is opposite in sign to voltage of the input signal from the solsyn system and is supplied to the first amplification stage valves control grids of the J-2M-1M amplifier in the fine channel.

As the generator voltage is always considerably higher than that of the synchronous system control signal, voltage picked up from the stabilization stage resistors is higher too at the first moment; hence at the amplifier input the opposite signal of the feedback system will predominate.

The value of voltage which appears across the stabilization system resistors depends on the speed of changing voltage across the drive electric motor armature.

If the amplifier and generator are considered to be an electric circuit which possesses inductance with a definite time constant and if this circuit is provided with the negative feedback (i.e. the output signal is sent to the input with the opposite sign) having the time constant exceeding the sum of the amplifier and generator time constants, this circuit may be considered a circuit with the time constant of the feedback system.

Thus if a signal is instantly sent to the amplifier from a voltage at the output (i.e. across the generator armature) increasing proportionally to the input signal not instantly but smoothly according to the exponent curve defined by the feedback system time constant.

Due to these properties of the stabilization system, the asynchronous follow-up system is protected against oscillations in case of remoting, changing the input signal and quick damping of oscillations is provided when the gun is set in the asynchronous position at high speeds.

Given in Fig. 47 is the example when the sight is moved from the synchronous position (lifted up).

The stabilizing capacitor is charged but the drive electric motor does not start operating.

Voltage supplied from the generator is insufficient for the drive electric motor operation but it increases continuously on the electric motor brushes.

Voltage supplied to the valves grids from the resistors is applied to voltage supplied from the amplifier armature winding (signal voltage). In this case the difference between voltages through both control windings of the asynchronous generator is constant the stabilization is provided.

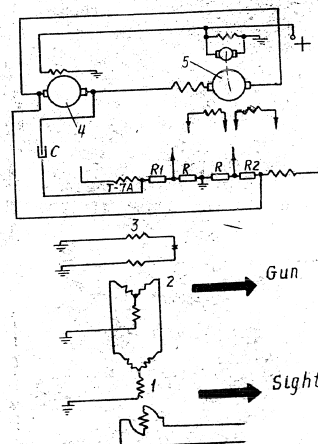


Fig. 4C. Stabilization (feedback) circuit of turret electrical drive.

- 1 - fine transmitting solenoid; 2 - fine receiving solenoid;
- 3 - input transformer; 4 - drive motor; 5 - generator;
- C - stabilizing capacitor;
- R_1, R_2 - stabilizing circuit resistors;
- R - resistor.

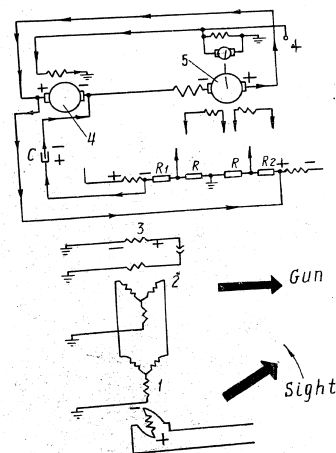


Fig. 47. Sight is moved from aligned position (sight is lifted up but gun did not begin to move).

Due to that the generator output voltage and drive electric motor speed are decreased.

When the gun speed of rotation attains the sight speed, voltage across the drive electric motor brushes stops changing and thus the capacitor C stops charging.

In this case the gun is controlled by signal voltage only. When the gun approaches the synchronous position the value of signal voltage decreases which causes decrease in voltage across the electric motor brushes.

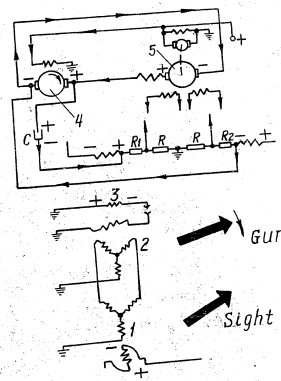


Fig. 48. Gun, having passed over aligned position, began to move back. Stabilizing capacitor C is discharging.

That, in its turn, results in the stabilizing capacitor C discharging. Discharged current will flow through R1 and R2 resistors and voltage picked up from the resistors and T-7A transformer secondary windings has similar direction. Thus the gun speed of movement to the synchronous position increases.

After the gun passes over the synchronous position, signal voltage changes to the opposite one and is opposite to the voltage picked up from R1 and R2 resistors.

Thus, the gun approaches the synchronous position and oscillations are damping.

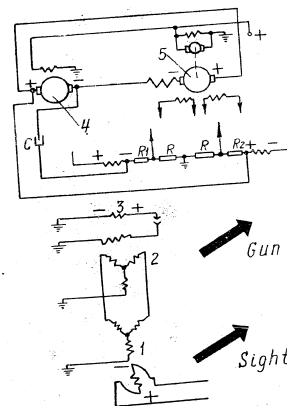


Fig. 49. Gun has reached aligned position and stopped.
Discharge of capacitor C is over.

C. CONTROL CIRCUITS

a) Selsyns Circuits

The transmitting selsyns stators circuits of the MHC-53A sighting set can be connected to the receiving selsyns stators circuits of the MB-65V turret either directly or through the differential selsyns of the air firing unit computer. The computer is actuated by switching on the BB4-2 computer switches on the MHC-53A sighting set and BB4-1 switch on the DL-54M auxiliary

control panel; in this case the **BL** a.c. switch should be switched on and control button pressed. Due to that the **PB4-1** and **PB4-2** relays are actuated and switch the circuits from the direct control to the control through the computer differential selsyns.

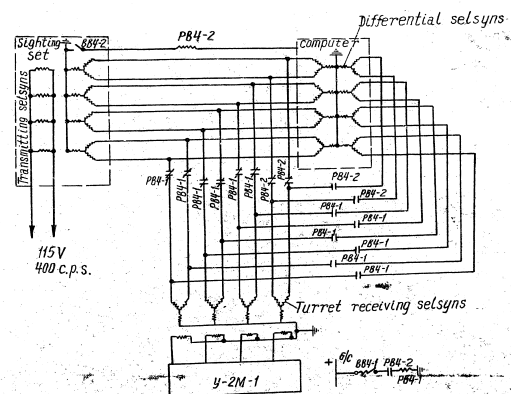


FIG. 50a Selsyn Circuits.

The distance to the target is introduced in the computer from the "Gamma" range finder radar or from the outer base range finder of the **KNC-53A** sighting set collimator sight.

The radar range finder is actuated by switching on the "Gamma" range finder radar switch (**BL**) and "Gamma" transmitter switch (**BHT**) located on the **BL-54M** auxiliary control panel.

By switching the range finder radar switch a power is supplied to the PBM relay; the latter, when actuated, switches the input of distance from outer base range finder to the "gamma" range finder radar.

b) Supply Circuits

supplied with 115 V a.c., 400 c.p.s. in the AN-500 turret remote control system are:

- air firing unit,
- gamma range finder radar,
- MC-50A sighting set,
- Y-2M-1 magnetic amplifier,
- Y-2M-1 amplifier unit,
- MC-1A fire interrupter.

The TP-3 gyro relay of the MC-50A sighting set is supplied with 36 V a.c., 400 c.p.s.

A.C. is supplied from the aircraft electric system.

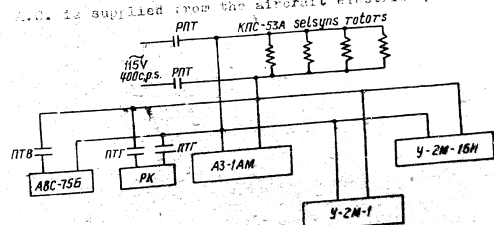


Fig. 51. A.C. Supply of AN-500 Turret Remote Control Units.

To connect the AP-65V target remote-control system unit to the aircraft electric system it is necessary to switch on the PB-54B-1 and KI switches on the BL-54M auxiliary control panel; due to that the a.c. (PHF) and interlocking (PI) relays, computer a.c. (HFB) and relay a.c. (PH) switching relays and range finder radar a.c. switching relay (HRT) installed in the KTK-54B control box, are actuated and a.c. flows to the remote-control system units.

c) Power Circuits of Motor-Generator Unit, Generator Drive Electric Motors and Circuits of Solenoid Clutches

To start the electric motor the motor-generator unit switch, located on the BL-54M aux. control panel, should be switched on.

After that the aircraft electric system voltage is supplied to the K-2 contactor winding.

The K-2 contactor (being actuated) supplies the electric system voltage to the electric motor of the motor-generator unit.

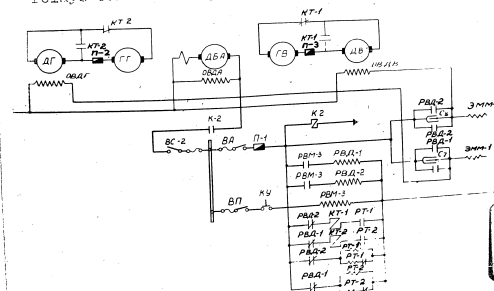
When switching the motor-generator unit through the normally-closed contacts of the PBM-1 and PBM-2 relays; the PT-1 and PT-2 time delay relays are actuated simultaneously; these relays close their normally-open contacts in the KT-1 and KT-2 contactor circuit.

The aircraft electric system voltage is supplied to the KT-2 contactor windings through the normally closed contacts of the PBM-1 and PBM-2 relays.

When the contactors are actuated, the electric motors, generator and solenoid clutches are started.

To supply voltage to the excitation windings and windings of the solenoid clutches locking the drive electric motors and connect the electric motor armatures to the armatures of the corresponding generators, it is necessary to switch on the A.C. switch located on the BL-54M aux. control panel.

When pressing the $\overline{K}$ control button located on the MK-3 sighting station, the PBM-3 relay is actuated; this relay closes its normally-open contacts in the circuits of the PBL-1 and PBL-2 relays control windings.



The PBL-1 and PBL-2 relays in their turn are actuated, close their normally-open contacts and supply power to the electric motor field windings both of elevation and azimuth gun aiming channels; power is supplied also to the 3MM-1 and 3MM-2 solenoid clutches which (when actuated) unlock the electric motor armatures.

At this time the normally-closed contacts of the PRT-1 and PRT-2 relays open in the supply circuits of the KM-1 and KM-2 contactors and PT-1 and PT-2 relays.

The KM-1 and KM-2 contactors are de-energized and connect the electric motor armatures to the armatures of the corresponding generators through their normally-closed contacts. All the above relays and contacts are located in the KVM-54B control box.

d) Circuit of Generator Unit Control Winding

(Fig. 50)

To connect the generator unit control winding circuit to the magnetic amplifier proceed as follows:

1. Switch on the a.c. and motor generator power switch located on the KVM-54B aux. control panel.
2. Press the KVM control button on the KVM-54B control panel.

In this case the PRT-2 and PRT-1 relays are actuated, their normally-open contacts are closed and voltage is applied to the windings of the PRT-1, PRT-2, PRT-1, PRT-1 relays through the KM-1, KM-2, KM-3, KM-4 limit switches of the 115V turret which are located in the reduction gears of the corresponding drives.

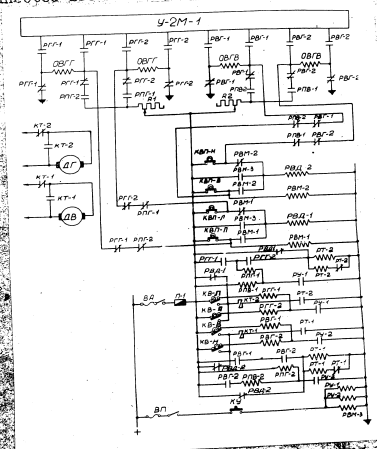
The field windings of the generator unit are connected to the magnetic amplifier through the normally-open contacts of the PRT-1, PRT-2, PRT-1 and PRT-2 relays and the turret becomes controllable.

Voltage from the aircraft plant system is also supplied to the windings of the PRT-1, PRT-1, PRT-2 and PRT-2 relays located in the KVM-54B control box.

The tail turret gun motion is restricted in four positions: extreme left, extreme right, extreme upper and extreme lower.

The tail turret gun motion is restricted in four positions: extreme left, extreme right, extreme upper and extreme lower.

When the turret approaches the extreme position, for example, left, the KP-I limit switch is actuated and the PNT-I relay winding is de-energized. The relay normally-open contacts open and the generator winding controlling the turret movement to the left is disconnected from the magnetic amplifier.



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Simultaneously the PTF-I relay normally-closed contacts close and energize the generator winding, controlling the turret movement to the left, to the aircraft electric system voltage through the pressing resistor.

In this case the generator produces voltages sufficient to keep the turret set to the stop.

With the KB-I left limit switch on, the circuit of the KT-2 dynamic braking contactor winding is energized (after the PTF-2 relay is switched off, the PT-2 relay contacts remain closed during time delay of this relay); the KT-2 contactor contacts are closed and azimuth electric motor armature is short-circuited, i.e. dynamic braking is obtained.

In this case the generator field winding is re-energized by the PTF-I relay contacts earlier than the KT-2 contactor is actuated.

On the expiration of the PT-2 relay time delay its contacts are open, the KT-2 contactor is de-energized and the electric motor armature is connected to the generator armature again.

With the KB-II right limit switch, KB-B upper limit switch and KB-II lower limit switch being open, the gun turning restriction circuits and dynamic braking circuits operate as described above, i.e. the PTF-2, PTF-I and PTF-2 relays and KT-1 dynamic braking contactor are actuated respectively.

When the pressing circuits are energized, the stowed position circuits are disconnected.

When rotating the starting set to the right from the extreme left stop, a voltage across the winding of the generator, controlling the turret movement to the right, increases, due to that the gun moves away from the stop and the KB-I limit switch closes.

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The PRT-1 and PRT-2 relay contacts are closed and both direction of the generator are connected to the magnetic coil. This is true for the other extreme positions.

To set the gun in the stowed position the RMT-1, RMT-2, RMT-3 and RMT-4 switches, located on the elevation and azimuth drives, are used.

The stowed position circuits are energized when the control button is released. For example, if in the center of the control button release the gun is in the left or right position, the RMT-1 limit switch is closed and current flows through the normally-open contacts of the PRT-1, RMT-2 relay to the generator winding and the gun moves to the right or left, the azimuth center line, the RMT-1 limit switch is switched off.

At the same time, current flow through the normally-closed contacts of the RMT-1 relay to the PRT-1 relay winding stops and the relay is de-energized.

The PRT-1 relay normally-open contacts open and break the supply circuit of the RMT-1 solenoid clutch and azimuth electric motor field winding.

When switching off the PRT-1 relay, its normally-closed contacts switch on the RT-1 dynamic braking contactor and RT-2 relay.

The RT-2 contactor is actuated and disconnects the circuit of the electric motor armature from the generator armature by its normally-closed contacts, and the electric motor armature is short-circuited by the normally-open contacts.

Thus when the turret reaches the stowed position the electric motor is fully de-energized and the armature is locked by the solenoid clutch.

With the turret in other positions the stowed position circuit functions in the similar way.

If during the turret control a.c. voltage of 115 V is off, the PB interlocking relay is de-energized and de-energizes the PY-1, PY-2, PY-3 relays by its normally-open contacts; hence the turret returns to the stowed position.

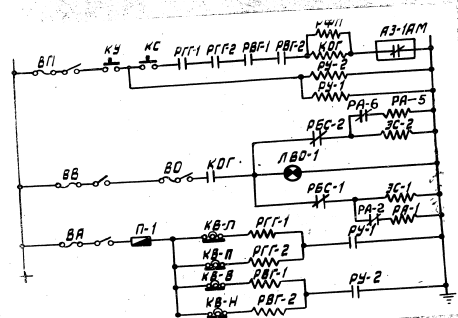


Fig. 5A. Firing Circuit.

2.2. Firing Control Circuit

The firing circuit with the motor is designed to switch the main line of the turret motor and motor-generator switch. The circuit is designed to switch the main line of the turret motor and motor-generator switch. The circuit is designed to switch the main line of the turret motor and motor-generator switch.

panel and BO fire control switch (right and left guns) located on the OM-54T main control panel.

When pressing the KW control button, power is supplied to the PV-1 and PV-2 control relays windings; the relays are actuated and switch on power supply of the PPI-1, PPI-2, PPI-3 and PPI-4 generator control relays by their normally-open contacts.

If the turret is not set in any of the extreme positions, the PPI-1, PPI-2, PPI-3 and PPI-4 relays are actuated and close their normally-open contacts in the KOT fire control contactor circuit.

The fire control system is ready for firing.

When the sighting set and the turret are in the synchronous position, the relay contacts located in the AD-1AM fire interrupter are also closed.

When pressing the KC fire control button, located in the KHC-58A sighting set, power is supplied through the closed contacts of the PPI-1, PPI-2, PPI-3 and PPI-4 relays to the KOT fire control contactor which is actuated and closes its normally-open contacts in the circuits of the 3C-1 and 3C-2 electric trigger controls.

The shot does not occur if the limit switches are open, i.e. the turret is within the restriction zone.

g) Recharging Circuit

Given in fig. 52 is the schematic diagram of the automatic recharger with the ammunition reserve counter. AL-27

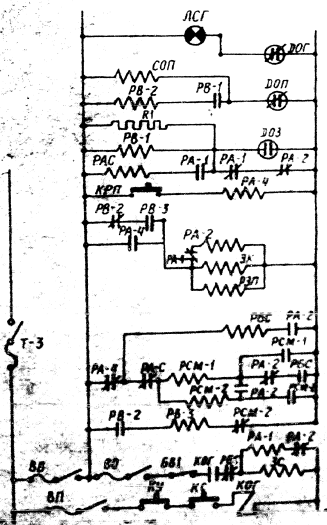


Figure 1. Switching Schematic Diagram of AT Automatic Recharge Counter.

The automatic recharger circuit is prepared for operation when the aux. circuit switch installed on the BM-34M aux. control panel is switched on.

When switching on the BM aux. circuits switch, the PB-1 time relay is energized through the normally-closed contacts of the PA-1 and PA-2 relays.

After the PB-1 relay is actuated it closes the normally-open contacts in the PB-2 time relay circuit.

As the initial position of the gun movable parts always corresponds to the front position, the gun front position transmitter (R01) is closed in this case.

The PB-2 relay is energized through the closed contacts of the PB-1 relay and front position transmitter; after the PB-2 relay is actuated, it opens the normally-closed contacts in the SC electro-pneumatic valve circuit and closes the normally-open contacts in the circuit of the PB-3 time relay, which (being actuated) closes its normally-open contacts in the electro-pneumatic valve circuit.

When pressing the K0 fire control button, the R01 fire control contactor is actuated and closes its normally-open contacts in the SC electric trigger control and PA-1 relay circuit.

The PA-1 relay is actuated, opens its normally-closed contacts in the PB-1 time relay circuit and closes its normally-open contacts in the BM automatic decharge relay circuit.

Thus with the SC fire control button pressed the PB-1 time relay is energized and the SC trigger control is energized. After the K0 fire control is actuated it releases the electric gear which releases the cartridge magazine breeching.

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If the gun fires without being ready to fire, the action of powder gases are thrown back into the breech and return to the front position until the action is ready to fire.

In this case the gun is ready to fire and the rear transmitter (RMT) is closed and the front transmitter (FMT) is open. The rear and front transmitters are consequently closed and open.

The PB-1 and PB-2 time relays are energized through the gun rear and front transmitters. The normally-open contacts of these time relays are closed and the normally-closed contacts are open. The rear and front transmitters are closed and open. The delay time required for the PB-1 and PB-2 time relays to operate is 1.0 second.

The PB-3 time relay is energized through the rear transmitter. Such state of the automatic recharger during the time the gun is armed, i.e. the recharger is ready to fire and the gun is ready to fire. The gun is ready to fire in case of delays during firing.

AUTOMATIC RECHARGER OPERATION IN CASE OF MISFIRE

In case of misfire, the gun movable parts are in the rear position. The gun "Fire ON" (FO) and front transmitters (FMT) are closed and rear transmitter (RMT) is open.

After time delay required for release, the PB-1 time relay is de-energized, opens the contacts in the PB-2 relay circuit.

The PB-2 de-energized relay after time delay required for release closes the normally-closed contacts in the 3K electrical circuit. The PB-2 relay circuit and opens the normally-closed contacts in the PB-3 time relay circuit.

As the PB-2 de-energized time relay does not open immediately its normally-open contacts in the circuit of the GK electro-pneumatic valve and PA-2 relay, the latter are supplied through the PB-2 and PB-3 relays contacts.

After the PA-2 relay actuating it closes its contacts in the circuit of the automatic recharger electro-pneumatic valve circuit. With the PA-2 relay the RCH electro-pneumatic valve and the RCH electro-pneumatic valve are actuated.

After the electro-pneumatic valve is actuated, compressed air is supplied to the gun pneumatic cylinder.

Under the action of compressed air the gun movable part is thrown back and then return to the front position under the action of compressed air and return spring. At this time the gun is charged and the "Fire On", front and rear transmitters are closed and open.

When the RCH gun transmitter is closed the PA-1 time relay is actuated and closes its contacts in the PB-2 relay circuit.

When the gun movable part, moving forward, open the gun rear transmitter and close the gun front transmitter, the PB-2 relay is actuated.

After the PB-2 relay is actuated it opens its contacts in the PA-2 relay and GK electro-pneumatic valve circuits and closes its contacts in the PB-3 relay circuit thus de-energizing the PA-2 relay and the electro-pneumatic valve.

The PA-2 relay being de-energized closes its normally-closed contacts in the PB-1, PA-1 and RCH-1 relays circuits and opens in the RCH-2 and RCH-3 relays circuits.

As the Pa-1 relay during pneumatic recharging is de-energized by the PFC time relay relay contacts, its normally-closed contacts in the PB-1 time relay circuit are closed.

Thus, after the SC electro-pneumatic valve is de-energized, the PB-1 time relay is additionally supplied through the PA-2 relays contacts during time delay. Contact PA-2 relays during the PFC time relay release.

The PB-1 relay is additionally supplied to prevent it from releasing its contacts earlier than the SC trigger control interlocking is completed.

At the beginning of pneumatic recharging, after the SC valve is actuated and closes by its contacts the PFC relay is hit, the latter relay is actuated, opens the SC trigger control circuit and closes the PCM-1 counting relay circuit.

After de-energizing the electro-pneumatic valve the PFC relay, the latter de-energizes the PFC interlocking time relay and the trigger control. After the electro-pneumatic valve is re-energized, the PFC time relay keeps its contacts in the trigger circuit open, and only after time delay required for release, the time relay closes its contacts in the SC trigger and Pa-1 relay circuits.

This time of the trigger control interlocking after the electro-pneumatic valve is switched off is necessary to eliminate residual compression in the gun pneumatic cylinder.

The difference in actuation and release time of the Pa-2 quick-acting relay and PFC time relay permits to supply power to the PCM-1 counting relay through the above relays contacts at the end of pneumatic charging only, to de-energize the Pa-1 relay and disconnect it from the trigger earlier than it will be de-energized by the PFC relay contacts at the beginning of pneumatic recharging.

Due to that the PA-1 relay release, depending on the trigger control inductance, is not delayed during their circuit breaking and a counting relay which indicates the beginning of pneumatic recharging is not needed.

If the KC fire control button is not released during pneumatic recharging the PA-1 relay and 9C trigger are again energized, the PA-1 relay is actuated, opens the PB-1 relay circuit and closes the PAC recharging droppage relay circuit.

After the trigger is actuated the trigger circuit is broken; if in this case the shot follows, the firing unit is returned again in the initial position.

If misfire occurs again the gun assembly parts will be in the front position and fire unit (ACD) and front (AF) transmitters will be closed and rear transmitter (RCD) will be open.

The PB-1 time relay being de-energized, its contacts in the PB-2 time relay circuit.

The de-energized PB-2 relay, after its time delay, releases, closes the PA-2 relay and 9C electromagnetic valve circuits; after these relay and valve are actuated the second pneumatic recharging begins in the sequence described above.

If after the second consequent pneumatic recharging, shot occurs, the firing unit returns again to the initial armed position and is ready to make two new consequent pneumatic rechargings.

Thus, when after one or two consequent pneumatic rechargings, the shot occurs, the firing unit returns again to the initial armed position and is ready to make new pneumatic rechargings.

But if after two consequent pneumatic rechargings the shot does not occur (with the KC fire control button pressed) the third consequent pneumatic recharging cannot be made as the PCM-2 counting

relay is actuated at the beginning of the second recharging and opens its normally-closed contact in the PB-3 time relay circuit.

The PB-3 relay after its time delay for release opens the contacts in the OK electropneumatic valve and PA-2 relay circuits; due to that the third consequent pneumatic recharging is not performed.

AUTOMATIC RECHARGER OPERATION IF GUN MOVABLE PARTS REMAIN IN FRONT POSITION

When the gun movable parts are stood in the front position, i.e. when the AOK "Fire On" and AOK front transmitters are closed and AOS rear transmitter is open, power is supplied to the electropneumatic valve group after time relay for retaining the PB-1 and PB-2 time relays.

After the OK electropneumatic valve is actuated, it permits compressed air access to the gun pneumatic cylinder; as the gun movable parts are not moved under the action of compressed air the "Fire On", front and rear transmitters remain in the initial position, i.e. the "Fire On" and front transmitters are closed and rear transmitter is open.

Thus, the PB-1 and PB-2 relays cannot be supplied from the transmitters.

In this case the OK electropneumatic valve group is not supplied from the PB-3 time relay.

After the electropneumatic valve group is de-energized, the PA-2 relay closes its contacts in the PB-1 relay.

The PB-1 relay is supplied through the PA-1 and PA-2 relays and the PA-2 relay is supplied through the PA-1 and PA-2 relays and the PA-1 relay is supplied through the PA-2 relay.

After the PB-1 relay is actuated it supplies power to the PB-2 time relay winding; after the PB-2 relay is actuated, it supplies power to the PB-3 time relay.

After actuation the PB-3 relay closes the contacts in the electro-pneumatic valve group circuit.

After time delay for release, the PB-3 time relay closes its contacts in the SC trigger unit and PA-1 relay circuits.

As the gun movable parts are not moved and thus recharging is not performed, the shot does not occur after the trigger unit actuation and the movable parts remain in the front position.

Simultaneously with the trigger unit the PA-1 relay is actuated and opens by its contacts the PB-1 time relay circuit.

After time delay for releasing the PB-1 and PB-2 relays, the gun movable parts are moved by compressed air again, i.e. the second pneumatic recharging begins.

If the gun movable parts are not shifted after two pneumatic rechargings, the third pneumatic recharging will not follow.

AUTOMATIC RECHARGER OPERATION IN CASE THE GUN MOVABLE PARTS ARE STOPPED IN THE REAR POSITION

When the gun movable parts are stopped in the rear position when the AOT "fire on" and AOT front transmitters are actuated the AOT rear transmitter is closed, and there are possible:

1. The gun movable parts can be moved by compressed air after pneumatic recharging (delay elimination).
2. The gun movable parts cannot be moved by compressed air after pneumatic recharging (delay elimination).

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In both cases power is supplied to the 3K electropneumatic valve group when the open 100H front transmitter de-energizes the PB-2 time relay.

If after the electropneumatic valve actuation, the gun movable parts are moved from their places, they occupy the front position and close the gun front transmitter.

After that the PB-2 relay is actuated and de-energizes the 3K electropneumatic valve group.

If after the first pneumatic recharging the shot occurs, the automatic recharger occupies the initial position.

If misfire occurs the second pneumatic recharging is performed. The third recharging will not follow.

If the gun movable parts are not moved from their place after the first pneumatic recharging, the second recharging is not performed as the gun movable parts which occupy the rear position do not close the 100H front transmitter.

Due to that the PB-2 relay is de-energized and does not supply power to the PB-3 relay winding.

After time delay for release, the PB-3 relay opens the 3K electropneumatic valve group circuit.

The PB-3 relay contacts in the electropneumatic valve group circuit remain open and power is not supplied to the electropneumatic valve group a second time.

OPERATION OF COUNTING RELAYS RESTRICTING THE NUMBER OF CONSEQUENT AUTOMATIC PNEUMATIC RECHARGINGS

Actuated at the beginning of the first pneumatic recharging is the PA-2 which opens by its contacts the PCN-1 counting relay circuit and closes the PCN-2 counting relay circuit.

After the PA-2 relay is actuated the PB-2 time relay is energized.

also, at the beginning of pneumatic recharging and closes the PCM-1 relay circuit. But at the beginning of the first pneumatic recharging neither the PCM-1 relay nor PCM-2 relay can be energized.

At the end of the first pneumatic recharging the PA-2 relay opens its contacts in the PCM-2 relay circuit and closes - in the PCM-1 relay circuit.

As the PSC time relay is disconnected after the PA-2 relay and has time delay for release, the PCM-1 relay can be supplied at the end of the pneumatic recharging through the contacts of the PA-2 and PSC relays during time delay for releasing the PSC relay.

After activation the PCM-1 relay locks itself by its contacts through which the PCM-2 second counting relay can be supplied at the beginning of the second pneumatic recharging.

At the beginning of the second pneumatic recharging the PA-2 relay closes its contacts in the PCM-2 relay circuit.

The PCM-2 relay is supplied through the closed contacts of the PA-2 and PCM-1 relays; after the PCM-2 relay is actuated it locks itself by its contacts and opens the PB-3 time relay circuit.

If the shot occurs after the second pneumatic charging the counting relays are de-energized by the contacts of the recharging dropage relay.

But if the shot does not occur again (three misfires in succession or strikes damaged) the third consequent pneumatic recharging is not performed, i.e. the de-energized PB-3 relay cannot close its contacts in the electromagnetic valve circuit and due to that the electromagnetic valve cannot be switched on.

AUTOMATIC RECHARGER OPERATION DURING MANUAL RECHARGING

When pressing the KI recharging button, the PA-4 relay is actuated and closes the 3K electropneumatic valve circuits by its normally-open contacts and opens the PA-2 relay circuit by its normally-closed contacts; due to that a pneumatic recharging is performed.

The PA-4 relay opens the counting relay and R3C time relay circuits by its second pair of normally-closed contacts.

Thus manual pneumatic recharging is not counted by the counting relay.

If automatic pneumatic rechargings have been counted before, the readings are dropped during manual recharging and the recharger can perform again two consequent automatic pneumatic rechargings.

n) Cartridge Belt Boosters Circuits

The ammunition boosters schematic diagram is given in Fig. 56.

As the operation of the ammunition boosters both for the left and right guns is identical, let us see the operation of the ammunition booster for one gun, left, for example.

Before flight the gunner should press the K3B-I button, i.e. this is the circuit of the ammunition booster manual switching.

This is done to preliminarily support the cartridge belt.

To boost automatically the cartridge belt it is necessary to switch on the B auxiliary circuit switch located on the MI-54M gun's control panel.

The gun fires, when fired, a current flows through the closed normally-open contacts of the PNM relay and normally-closed contacts of the PNM-2 relay to the M-3 contact.

simultaneously with the 1-2 contacts. The 1-2 relay is actuated which puts in B1 the normal-closed contacts the 1-2 relay.

to prevent the contractor from releasing the contents at the
 onset of listening over power until the H-10-100
 contractor is contacted as detailed in the contractor's SOP.

0030-2

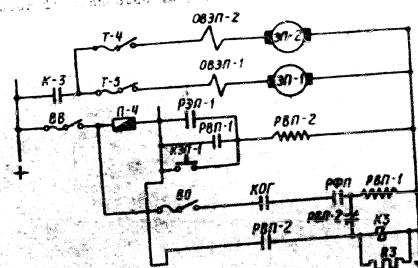


Fig.56. Schematic Diagram of Left Immunization Booster.

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After fire is stopped i.e. the KC fire control button is released the PHL-1 relay contacts are open after time delay and PHL-2 relay is de-energized.

PHL-2 time relay after its time delay disconnects the K-3 contactor from the aircraft system.

Thus, after releasing the fire control button the ammunition electric motors operate within the total time delay of the PHL-1 and PHL-2 relays which is sufficient to produce necessary support for the cartridge belt.

The ammunition booster is switched on also during the gun recharging. In this case the PHL-1 relay is actuated.

Current flows through the closed normally-open contacts of the PHL-1 relay to the PHL-2 relay windings; the PHL-2 relay is actuated and energizes the K-3 contactor by its normally-open contacts. The contactor is actuated and current flows through the circuit breakers to the ammunition boosters electric motors.

1) Ammunition Reserve Counter Circuit

Provided in the gun fire control circuits are the ammunition reserve counters to check ammunition reserve.

Installed on the QM-547 main control panel at the gunner's place together with the ammunition reserve counter are QMC-1 and QMC-2 warning lights.

The counters are supplied from the AM-27 automatic recharger so that they operate depending on the AM front transmitters.

3) Camera Gun Circuit

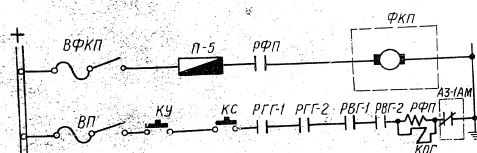


Fig. 57. Camera Gun Circuit.

Installed on the KHC-53A sighting set is the HAV-457 camera gun to check for correct sighting.

When firing, switch on the following switches:

- ВФКП a.c. switch,
- НА motor-generator unit switch,
- ВБ aux. circuits switch,
- ВФКП camera gun switch,
- КОГ fire control switch located on the CH-54T main control panel.

Also press the КУ control button and КС fire control button located on the KHC-53A sighting set.

In this case power is supplied to the КОГ fire control contactor and ВФКП camera gun relay.

The camera gun relay is actuated and closes its normally-open contacts in the camera gun motor circuit.

к) Camera Gun Heating Circuit

To switch on the camera gun heating, it is necessary to switch on the ВФКП camera gun switch on the ФЛ-РАМ aux. control panel.

In this case "plus" of the aircraft electric system is connected to heat the camera gun.

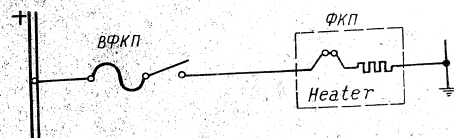


Fig. 28. Switching Circuit of Camera Gun Heater.

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